Journal of the Arkansas Academy of Science

Volume 47 Article 1

1993

Proceedings of the Arkansas Academy of Science - Volume 47 1993

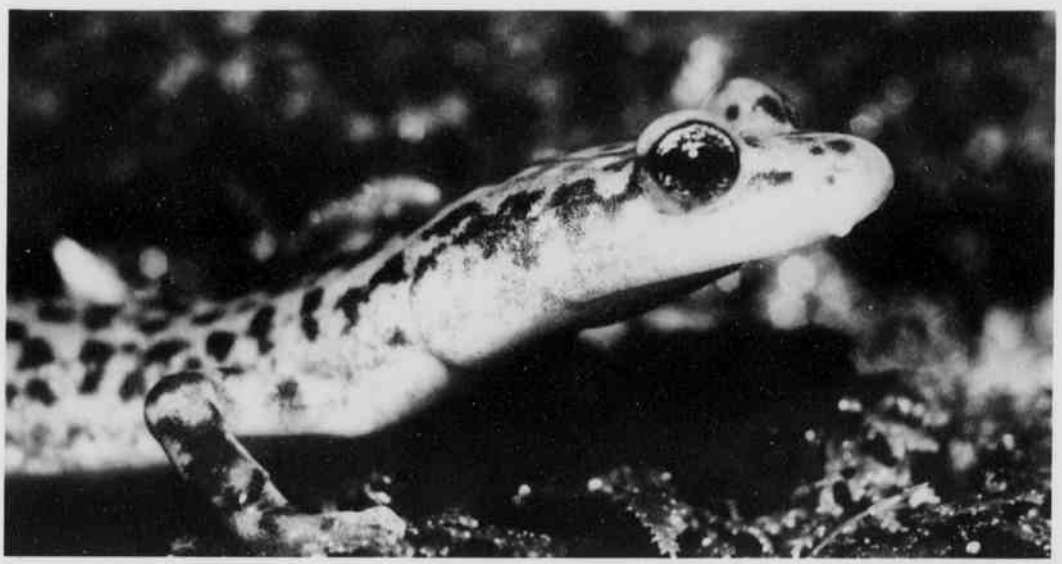
Academy Editors

Proceedings of the

CODEN: AKASO
ISBN: 0097-4374

ARKANSAS ACADEMY OF SCIENCE

VOLUME 47
1993



ARKANSAS ACADEMY OF SCIENCE
DEPT. OF NATURAL SCIENCE
MONTICELLO, ARKANSAS 71655

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Flora Haas, 1934
H. H. Hyman, 1935
L. B. Ham, 1936
W. C. Munn, 1937
M. J. McHenry, 1938
T. L. Smith, 1939
P. G. Horton, 1940
I. A. Willis, 1941-42
L. B. Roberts, 1943-44
Jeff Banks, 1945
H. L. Winburn, 1946-47
E. A. Provine, 1948
G. V. Robinette, 1949
John R. Totter, 1950
R. H. Austin, 1951
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M. Ruth Armstrong, 1955
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C. E. Hoffman, 1959
N. D. Buffaloe, 1960
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Trumann McEver, 1962
Robert Shideler, 1963
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Richard K. Speairs, Jr. 1990
Robert Watson, 1991
Michael W. Rapp, 1992
Arthur A. Johnson, 1993

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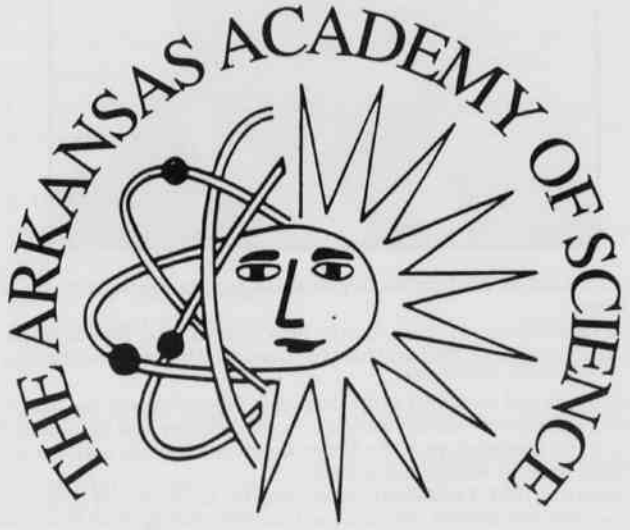
UNIVERSITY OF ARKANSAS AT PINE BLUFF
UNIVERSITY OF CENTRAL ARKANSAS, Conway
UNIVERSITY OF THE OZARKS, Clarksville

EDITORIAL STAFF

COVER: Cave salamander, *Eurycea lucifuga*, from Blowing Cave, Independence County, Arkansas. Photo by Stan Trauth

ARKANSAS ACADEMY OF SCIENCE 1993



APRIL 2-3, 1993
77th ANNUAL MEETING

ARKADELPHIA

In Memoriam: Leo J. Paulissen, 1915 – 1993

Dr. Leo Paulissen passed away on April 11, 1993 at Washington Regional Hospital in Fayetteville. He is survived by his wife, Rita, of Fayetteville, three sons, a daughter, two brothers, and a sister.

The son of Andrew and Marie Paulissen, he was born on November 8, 1915 at Kankakee, Illinois where he attended high school. He received his B.S. with highest honor from Bradley Polytechnic Institute in 1941 and his M.S. from the University of Chicago in 1949. His Ph.D. was completed in 1954 at Washington University in St. Louis.

His professional career began as a bacteriologist and serologist at the diagnostic laboratories of the Illinois Department of Health in Chicago, Illinois from 1946 to 1950. He was a research assistant and later a research associate in bacteriology and immunology at Washington University between 1951 and 1954. He joined the Department of Botany and Bacteriology at the University of Arkansas as a Research Associate in 1954, advancing to the academic rank of professor in 1968, a position he held until his retirement in 1986.

I first met Leo when I came to the University in 1957. I will always remember his kindness and help in finding a place to live. It has been a friendship that has lasted for many years. I remember him particularly well as a hard-working colleague who was always there to help with problems concerning departmental administration, scheduling, and managing the microbiology programs. His service fro many years as Director of Summer Science Institutes sponsored by the National Science Foundation was an outstanding contribution to further training of high school science teachers and the consequent improvement in science education in Arkansas and the surrounding states.

His most notable research was on the effects of ionizing radiation on cellular and humoral immunity. He continued research in bacteriology and immunology during his later years, but because of heavy teaching and administrative loads his more recent research activities speak mostly through the theses and dissertations of his many graduate students.

In addition to his regular laboratory work in microbiology, Leo was an excellent field man. He was particularly interested in butterflies and moths and made extensive collections. He was meticulous in identification and documenting the distribution of his collections, most of which are now deposited with the Department of Entomology Museum. I recall the many pleasant times we shared on field trips to different types of forest and prairie ecosystems. He was busy collecting moths and butterflies while I was collecting field data for studies on plant communities.

After retirement as emeritus professor, Leo was in his office nearly every day documenting his work and writing until he was no longer able to be there because of failing health. His office contained shelves and file cabinets stacked with boxes of insect collections, books, and professional journals arranged as tunnels throughout except for a small space occupied by his desk and one chair for visitors. However, when asked for information, Leo knew exactly where everything was and could almost always locate any item he wanted immediately.

He was absolutely devoted to his undergraduate teaching and work with his graduate students. I have been unable to determine how many students he taught, but I can say that his undergraduate students numbered in the thousands, and he trained more microbiology graduate students than anyone else in the department. His former graduate students today occupy important positions as university faculty members or research workers and administrators with government agencies and in industry, attesting to the soundness of his tutelage.

He was an army veteran serving in the Pacific Theater during World War II. He received the Pacific campaign medal, two bronze stars, a meritorious unit award, and the World War II victory medal.

He was a member of the American Society for Microbiology and a long-time member of the Arkansas Academy of Science. He served the Academy for many years as a member of the executive committee, Chairman of the Arkansas Biota Survey Committee, and Director of the Westinghouse Talent Search Committee, which sought to recognize potential young scientists in the high schools. Also he was former Secretary-Treasurer of the U. of A. Chapter of Sigma Xi and was serving as its President at the time of his death.

He was held in highest regard by his colleague, students, and friends for his integrity and competence. We are all privileged to have known and worked with him, and we all miss him.

Edward E. Dale, Jr.
Department of Biological Sciences
University of Arkansas
Fayetteville, AR 72701

ARKANSAS ACADEMY OF SCIENCE

ANNUAL FINANCIAL STATEMENT

(1 JANUARY 1992 TO 31 DECEMBER 1992)

ANNUAL MEETING 2-3 APRIL 1993
HENDERSON STATE UNIVERSITY, ARKADELPHIA, AR

George Harp, President | **James Peck**, President-Elect | **John D. Rickett**, Secretary

Robert Wiley, Treasurer | NAAS Delegate | **Henry Robison**, Historian

Secretary's Report

FIRST BUSINESS MEETING

Members present: 23

1. President Art Johnson opened the meeting at 1132 hrs. by recognizing Dennis McMasters who introducted Dr. Joe Wright, Dean of Ellis College of Arts & Sciences to offer a formal welcome to the HSU campus.
2. President Johnson recognized the Secretary who called attention to available copies of the minutes from the 1992 Business Meeting and asked for corrections and comments (in writing) before the Second Business Meeting. The Secretary also asked members to keep the copy of the Academy Constitution attached to the minutes.
3. President Johnson recognized Treasurer Robert Wiley who distributed copies of the Academy's financial report and explained investments, earnings, and disbursements. He explained that this is the transition year for changing our fiscal year to 1 January - 31 December.

FUNDS

Balance on 1 January 1992		21,373.85
Total Income (Page 2)	13,439.60	
Total Expenses (Page 3)	-12,178.91	
Balance for the Year	$1,260.69	1,260.69
TOTAL FUNDS AS OF 31 DECEMBER 1992		**$22,634.54**

DISTRIBUTION OF ACCOUNTS

Interest Bearing Checking Account (Union Bank and Trust Co., Monticello, AR)	2,271.12
Certificates of Deposit	
Dwight Moore Endowment (Heritage Bank - A Federal Savings Bank - Monticello - No. 508938 - 3.50% Int.)	2,045.70
Life Membership Endowment (Heritage Bank - A Federal Savings Bank - Monticello - No. 508910 - 3.50% Int.)	9,244.90
AAS Endowment (Heritage Bank - A Federal Savings Bank - Monticello - No. 509173 - 3.50% Int.)	5,527.72
AAS General CD 1 (Heritage Bank - A Federal Savings Bank - Monticello - No. 01-00509066 - 3.30% Int.)	2,245.10
AAS General CD 2 (Heritage Bank - A Federal Savings Bank - Monticello - No. 509181 - 3.50% Int.)	1,300.00
TOTAL	**$22,634.54**

Respectfully Submitted

Robert W. Wiley, AAS Treasurer

FINANCIAL STATEMENT, ARKANSAS ACADEMY OF SCIENCE

INCOME: 1 January 1992 to 31 December 1992

1. INDIVIDUAL MEMBERSHIPS		
a. Regular	2,925.00	
b. Sustaining	460.00	
c. Sponsoring	150.00	
d. Life	400.00	
e. Associate	200.00	
	4,135.00	4,135.00
2. INSTITUTIONAL MEMBERSHIPS		2,000.00
3. PROCEEDINGS, LIBRARY SUBSCRIPTIONS		501.50
4. PROCEEDINGS, MISC. SALES (UAF)		2,352.45
5. PROCEEDINGS, PAGE CHARGES		2,55O.00
6. ANNUAL MEETING		486.35
7. INTEREST		
a. Interest Bearing Checking Account	115.36	
b. Dwight Moore Endowment	100.68	
c. Life Membership Endowment	471.17	
d. AAS Endownment	218.45	
e. AAS General CD's	213.64	
	1,119.30	1,119.30
8. ENDOWMENT DONATIONS		
a. Dwight Moore Endowment	130.00	
b. AAS Endowment	165.00	
	295.00	295.00
TOTAL INCOME		**$13,439.60**

FINANCIAL STATEMENT, ARKANSAS ACADEMY OF SCIENCE

EXPENSES: 1 January 1992 to 31 December 1992

1.	AWARDS		
	a. Brad Johnson (#589)	50.00	
	b. Jay Sims (#590)	50.00	
	c. John Peck, Plaques - Arkansas Science Talent Search (#591)	158.25	
	d. Arkansas Junior Academy of Science (#588)	250.00	
	e. Arkansas Science Fair Association (#587)	400.00	
		908.25	980.25
2.	PROCEEDINGS		
	a. Phillip's Litho (Vol. 45) (#586)	9,397.07	
	b. Phillip's Litho (Vol. 45) (#593)	32.25	
	c. Linda Lee, Editorial Consultant Vol. 45 (#584)	500.00	
		9,929.32	9,929.32
3.	OFFICE EXPENSES		
	a. President's Office Art Johnson (#596)	29.00	
	b. Secretary's Office, John Rickett (#594)	398.63	
		427.63	427.63
4.	ANNUAL MEETING EXPENSES (UAF)		
	a. Conway Trophies & Awards (#585)	42.40	
	b. Dr. Lincoln Brower (Speaker) (#592)	725.76	
		767.96	767.96
5.	NEWSLETTERS		
	a. UAM Department of Forest Resources (#582)	41.29	
	b. UAM Department of Forest Resources (#599)	39.96	
		81.25	81.25
6.	DUES		
	a. National Association of Academies of Science (#581)		43.50
7.	MISCELLANEOUS		
	a. Hendrix College, Refreshments (#598)		21.00
	TOTAL EXPENSES		$12,178.91

4. President Johnson recognized Historian Henry Robison who reported that this meeting is the 77th annual meeting of the Academy. Henderson State University hosted the meeting in 1941, 1968, 1982, and 1993.

5. President Johnson recognized *Proceedings* Editor Harvey Barton (and Stan Trauth, in cooperation) who reported that volume 46 is ready to be picked up at the registration desk. He also asked section chairs to collect manuscripts intended for publication. Trauth moved (2nd, Barton) that the Academy appropriate $700 (to include $200 in new appropriation for consultant's travel reimbursement) to support editorial consultation.

6. President Johnson recognized *Newsletter* Editor Dick Kluender (report given by Robert Wiley) for a report. Wiley explained that the Forest Resources Department at UAM helps support the *Newsletter*, but in the event that support ceases, he moved (2nd, H. Robison) that the Academy appropriate $800 to support the production of the *Newsletter*.

7. President Johnson read a letter from the Nominating Committee. Peggy Rae Dorris and Jim Daly are nominated for Vice President, and Stan Trauth is nominated for *Proceedings* Editor.

8. Johnson called for a report from the Science Education Committee, but none was available.

9. Johnson announced the members of the Auditing Committee (Alex Nisbet, Chair, Elwood Shade, and Harriett Jansma) and the Resolutions Committee (Joe Guenter, Chair, Mark Karnes, and Rudy Eichenberger).

10. Johnson recognized Mike Rapp who reported that the Arkansas Science Fair Association is active and submitted the following data on involvement:

Year	Cent	NCen	N.E.	N.W.	SCen	S.E.	S.W.	State	JrAcad
1987	100	150	115	192	150	135	143	243	67
1988	100	110	100	174	200	135	116	248	94
1989	210	94	85	169	150	125	0	199	65
1990	221	75	81	140	181	115	71	229	83
1991	200	70	99	132	164	124	72	219	62
1992	156	65	95	120	169	100	41	228	49
1993				134	169	152	106		

Rapp moved (2nd, Jim Peck) the Academy appropriate $400 to support the regional science fairs during the next year. Rapp also reported that the Junior Academy is functioning well, and requested (for Pat Knighten, Director; 2nd, Jim Peck) the Academy appropriate $250 to purchase awards for Junior Academy winners.

11. Johnson recognized John Peck who reported that the Westinghouse Science Talent Search is very active. Peck moved (2nd, G. Harp) the appropriation of $200 to support this program.

12. Johnson called for reports on awards:
    a. Mike Rapp reported that Melissa Mazumder won the Junior Academy competition last year.
    b. Dennis McMasters explained that, at this meeting, first, second, and third place awards in both physical and life sciences at both undergraduate and graduate levels will be given. Sigma Xi is responsible for the graduate awards.
    c. Johnson announced that the Arkansas Chapter of the Association of Women in Science will present an award.
    d. Rapp explained plans being developed for the Academy to recognize the outstanding high school science teacher each year and moved (2nd, John Peck) acceptance (Appendix A).

13. Johnson recognized George Harp who announced plans not yet finalized for the 1994 meeting. Most probable is a meeting co-sponsored by University of Arkansas at Pine Bluff and National Center for Toxicological Research.

14. Johnson called for other items of old business. None.

15. Johnson called for new business items. None.

16. Johnson again recognized Dennis McMasters who announced places to eat lunch and that approximately 25 banquet tickets are still available. He also announced that Friday afternoon refreshments will be provided by AWIS, Arkansas Chapter.

17. Johnson recognized the current Academy officers and requested members express their appreciation to them.

18. President Johnson requested a motion to adjourn at 1210. So moved by G. Harp (2nd, H. Robison).

SECOND BUSINESS MEETING

Members present: 51

1. President Johnson called the meeting to order at 1200 hrs. and recognized the Secretary who, having received no comments or corrections to them, requested approval of the minutes of the 1992 business meetings (2nd, G. Heidt). Passed, voice vote.

2. Johnson recognized Treasurer Wiley for a brief reference to copies of the financial report and Alex Nisbet, Chair of the Auditing Committee for a report. Nisbet reported that the financial statement prepared by Wiley was in good order and accurate. Acceptance of the report passed by voice vote.

3. Johnson again recognized the Secretary for a recap of the several requests for appropriations submitted at the first business meeting as follows:

   a. $700 for editorial consultation for *Proceedings*, vol. 47
   b. $800 for possible use for the *Newsletter*
   c. $400 for the Science Fair Association
   d. $250 for the Junior Academy of Science
   e. $200 for the Westinghouse Science Talent Search
   SUM: $2350

   Passed as a group by voice vote.

4. Johnson recognized M. Rapp for a restatement of the proposed science teacher award to be begun next year by the Academy Passed by voice vote.

5. Johnson called for recognition of any new Academy members; none were present. He then asked life members to stand and be recognized.

6. Johnson recognized Joe Guenter, Chair of Resolutions Committee who submitted resolutions of thanks to all who helped make this meeting a success (Appendix B).

7. Johnson recognized Dennis McMasters for announcement of award winners as follows:

	Undergraduate	*Graduate*
life sciences		
first	Robert Cowherd, UALR	Anthony Hope, ASU
second	Mike Eckles, Hendrix	Walter Heckathorn, UAF
third	Connie Baber, HSA	Karen Stone, UALR
physical sciences		
first	E. E. Ward, UCA	T. H. Dhayagude, UAF
second	Mandy Prosser, Harding	Charles Byrd, UALR
third	Edward Boone, Harding	Lawrence Fitz, UAPB

8. Johnson recognized a representative from AWIS to present their awards. Linda Moss (ASU) won at the graduate level, and Robbin Long (UALR) won the undergraduate award.

9. Johnson asked for other old business by way of --
   a. asking that volunteers for regional science fair directors notify Mike Rapp
   b. encouraging that we cultivate productive interactions with the Arkansas Science Teachers Association (ASTA-1) and the Arkansas Science and Technology Authority (ASTA-2)
   c. representatives from the various campuses take unclaimed copies of the *Proceedings* back with you
   d. submit any memorabilia and historical information to Henry Robison

10. Johnson asked for any new business. Robert Watson (for Tome Lynch) announced the Science Education Committee will not meet.

11. Johnson restated that Peggy Rae Dorris and Jim Daly had been nominated for Vice President and Stan Trauth for *Proceedings* Editor. He also referred to the confusion of whether the new Editor would finish the retiring Editor's current term or begin a new five-year term. The executive Committee decided that the new Editor would begin a new five-year term. Johnson then called for any nominations from the floor for either office. None came. Robert Watson moved (2nd, James Peck) that Stan Trauth be elected by acclamation. Passed by voice vote. Paper ballots were then passed out for voting on Vice President.

Ballots were collected and counted by James Peck and John Rickett.

12. Johnson asked the members join in applauding those who presented papers at this meeting. Applause was also offered to AWIS for providing refreshments. Johnson distributed appreciation to all who had helped him over the past year.

13. Upon completion of ballot counting, Johnson announced the new Vice President was Peggy Rae Dorris.

14. Johnson then turned the gavel over to new President George Harp. Harp presented Art Johnson and Harvey Barton with plaques of appreciation of service.

15. Harp appointed a Constitution Committee of James Peck, Peggy Rae Dorris, and John Rickett to prepare guidelines for the filling of an unexpired officer's term and to consider adding the standing committees descriptions as by-laws to the Constitution. He also requested input from the membership in these matters.

16. Harp asked for announcements. Stan Trauth asked for all manuscripts to be submitted.

17. The meeting was adjourned at 1242 hrs.

--- Respectfully submitted
John Rickett, Secretary
28 April 1993

APPENDIX A

"Teacher Recognition Award - Proposal"

Background:

Many pre-college teachers devote time and energy to their profession and deserve recognition for their successful work. A number of organizations provide some recognition for outstanding science teachers in our state. The Arkansas Academy of Science can also provide encouragement and recognition through an award that stresses a particular emphasis of the Academy.

Teachers currently are recognized through their students' work presented through the Junior Academy of Science, Arkansas Science Talent Search, Junior Science and Humanities Symposium, and regional and state science fairs. The Arkansas Department of Education organizes a committee to select twelve state nominees (three each in the areas of elementary math, elementary science, secondary math, and secondary science) for the national Presidential Teaching Awards, and four Arkansas winners are given $7500 each to be spent on their classroom. In 1992, two previous Presidential Teaching Awardees from our state were chosen for the prestigious "Milliken Award" - a national (unrestricted) award of $25,000. The Central Arkansas Section of the American Chemical Society presents an award of $150 each year to the "high school chemistry teacher-of-the-year" and treats the teacher and his/her family at its annual awards banquet. Arkansas members of the National Association of Biology Teachers and American Geological Institute also nominate teachers for national awards.

Any award or recognition, whether a certificate, a meal, or a monetary award, shows an appreciation for the work of the teachers and serves to encourage those who are fully dedicated to their students. The Academy can join those other organizations that are recognizing the work of excellent teachers by selecting one or more recipients of an annual award. Current resources of the Academy are sufficient to support a small annual award. The Academy's Development Committee could seek additional contributions as needed.

Proposal:

The Arkansas Academy of Science will present an annual "Outstanding Teacher Award" to a pre-college science teacher in our state whose example and encouragement to students has facilitated the students' research and careers in science. The award may be given on the basis of excellence for work during the previous year or for work done over a career of teaching. The Science Education Committee is charged with the task of selecting the awardee and will prepare a suitable certificate or plaque for presentation at the spring Academy meeting. The recognition also will include a monetary award of $100. The Science Education Committee is encouraged to select the awardee sufficiently in advance of the spring meeting to invite the awardee and his/her family to the Academy's banquet, at which time the award will be presented. Further, the Science Education Committee will arrange for suitable publicity recognizing the awardee and will ask the Arkansas Science Teachers Association to announce the award at its annual meeting the following fall. Should additional funding be obtained, the number of annual awards could be increased to as many as five per year.

-- Mike Rapp

APPENDIX B

RESOLUTIONS

RESOLUTIONS FOR THE 77TH ANNUAL MEETING OF THE ARKANSAS ACADEMY OF SCIENCE, HENDERSON STATE UNIVERSITY:

Secretary's Report

BE IT RESOLVED THAT: the members of the Arkansas Academy of Science express their sincere appreciation to the faculty, staff, and students of Henderson State University for hosting our 1993 meeting. We especially thank Dennis McMasters and the local arrangements committee for all of their efforts on behalf of the membership to make this meeting such a success. Thanks also go to the individual presenters, faculty advisors, and judges of student papers. Sincere appreciation goes to Arthur Johnson, President; George Harp, President-Elect; Michael Rapp, Past President, and the remaining members of the Executive Committee -- James Peck, Vice President; John Rickett, Secretary; Robert Wiley, Treasurer; Stan Trauth, *Proceedings* Editor; Dick Kluender, *Newsletter* Editor; and Henry Robinson, Historian.

BE IT RESOLVED THAT: the members of the Arkansas Academy of Science express sincere appreciation to those working with the various associated activities of the Academy and the meeting -- to Pat Knighten, Joyce Hardin, and Marian Douglas for directing the Junior Academy of Science; to Mike Rapp for directing the Arkansas Science Fair Association; to Tom Palko for directing the Westinghouse Scienct Talent Search; and to Kathryn Schinn, Veryl Board, Larry Mink, Laurin Wheeler, John Hardee, Jim Edson, and Tim Daniels for directing the regional science fairs. We further express our appreciation to the meeting section chairs -- Clifton Orr, Biomedical; J. D. Wilhide, Vertebrate Zoology; James Rasmussen, Botany; John Aardee, Biochemistry & Organic Chemistry; Jules Mollere, Physics, Math & Geology; James Graham, Inorganic & Physical Chemistry; Carson Davis, Physics & Engineering; Billy Teague, Aquatic & Environmental Biology; Julia Bollinger, Vertebrate & Invertebrate Zoology; Ann Bragg, Microbiology & Molecular Biology; and Jane Dunn, Science Education. Finally we thank Richard Hoover for this most interesting presentation of "The Unseen World" concluding the banquet.

BE IT RESOLVED THAT: the members of the Arkansas Academy of Science recognize Harvey Barton for his work as Editor of the *Proceedings*, and we thank him for his services.

Joe Guenter
Mark Karnes
Rudy Eighenberger

MEMBERS 1993

LAST NAME	FIRST MI	INSTITUTION
Adams	Al	Univ. of Arkansas at Little Rock
Addison	Stephen R.	University of Central Arkansas
Al-Khyri	Jameel M.	University of Arkansas/Fayetteville
Al-Zaaim	Sam	University of Arkansas at Little Rock
Allen	Robert T.	University of Arkansas at Fayetteville
Annett	Cynthia	University of Arkansas at Fayetteville
Bacon	Robert	University of Arkansas at Fayetteville
Bailey	Claudia	University of Arkansas at Fayetteville
Baker	Max L.	University of Arkansas/Medical Sciences
Ball	Kenneth M.	El Dorado Public Schools
Baltosser	William H.	University of Arkansas at Little Rock
Barber	Gwen	
Basford	Adelphia M.	Henderson State University
Bass	Ralva	University of Central Arkansas
Bates	Vernon	
Beadles	John Kenneth	Arkansas State University
Bennett	J. Edward	Arkansas State University
Benson	Ann Marie	University of Arkansas/Medical Sciences
Bhuvaneswaran	C.	University of Arkansas/Medical Sciences
Bickle	Elaine	Univ. of Arkansas at Little Rock
Bowman	Leo H.	Arkansas Tech University
Bragg	Jimmy D.	Henderson State University
Bragg	Ann T.	Garland County Community College
Braithwaite	Wilfred J.	University of Arkansas at Little Rock
Breen	David	Mississippi County Community College
Brown	Art	University of Arkansas
Brown	William D.	University of Arkansas at Fayetteville
Buchanan	Roger A.	Arkansas State University
Burnside	Gaylen	University of Arkansas at Little Rock
Cady	Susan	Arkansas State University
Caldwell	Jody	University of Arkansas at Little Rock
Chapman	Stanley L.	University of Arkansas at Fayetteville
Cisar	Cindy	University of Arkansas at Fayetteville
Clayton	Frances E.	University of Arkansas at Fayetteville
Cochran	Betty S.	U.S. Forest Service
Cohoon	Richard R.	Arkansas Tech University
Cole	David	Harding University
Collins	Joseph T.	University of Kansas
Compadre	R. Lilia	University of Arkansas/Medical Sciences
Cordova	Robert M.	Cordco Consulting
Crisp, Jr.	Robert M.	University of Arkansas at Fayetteville
Culwell	Donald	University of Central Arkansas
Dalske	Fred	University of Central Arkansas
Daly	James J.	University of Arkansas/Medical Sciences
Daniels	James T.	Southern Arkansas University/Tech Br.
Darsey	Pat	Holy Souls Catholic School
Daster	Robert H.	Arkansas Highway & Transp. Dept.
David	Stanley N.	Arkansas State University
Davies	David L.	University of Arkansas/Medical Sciences
Davis	Jerry W.	USDA, Forest Service
Demarest	Jeffery R.	University of Arkansas at Fayetteville
Desrochers	Patrick	Univ. of Central Arkansas
Doran	Ronald H.	Harding University
Dorris	Peggy Rae	Henderson State University
Doster	Robert H.	Ark. Highway &Transp. Dept.
Douglas	Marian	University of Arkansas at Little Rock
Duhart	Benjamin T.	University of Arkansas at Pine Bluff
Dunn	Jane	Henderson State University
Dussourd	David	University of Central Arkansas
Edwards	Richmond	
Eichenberger	Rudolph J.	Southern Arkansas University
Eldridge	Hudson B.	University of Central Arkansas
Engelken	Robert	Arkansas State University
England	Don	Harding University
Epperson	Claude E.	University of Arkansas/Medical Sciences
Fifer	E. Kim	University of Arkansas/Medical Sciences
Fijan	Nikola	Univ. of Arkansas at Pine Bluff
Fletcher	M. Doug	Riceland Foods Inc. (ASU)
Floyd	E. P. (Perk)	U.S. Public Health Service
Foti	Thomas L.	Natural Heritage Commission
Francis	Paul B.	University of Arkansas at Monticello
Freiley	Kenneth	University of Central Arkansas
Fuller	Gary	University of Arkansas at Little Rock
Gagen	Charlie	Arkansas Tech University
Gaiser	Jack	University of Central Arkansas
Gentry	Joe P.	Arkansas Science & Technology Authority
George	Michael	Arkansas State University
Gildseth	Wayne	Southern Arkansas University
Gilmour	John T.	University of Arkansas at Fayetteville
Goforth	Calvin	Univ. of Arkansas at Fayetteville
Goforth	R. R.	University of Arkansas at Fayetteville
Gooch	Jan W.	Georgia Institute of Technology
Gray	Wayne L.	University of Arkansas/Medical Sciences
Green	Reid	U.S. Geological Survey
Griffin	Edmond E.	University of Central Arkansas
Griggs	Gaston	John Brown University
Gross	Mark	University of Arkansas at Little Rock
Hanebrink	Earl L.	Arkansas State University
Hanson	Richard H.	University of Arkansas at Little Rock
Harris	John L.	Arkansas Highway & Transportation Dept.

LAST NAME	FIRST MI	INSTITUTION
Harvey	Michael J.	Tennessee Tech University
Hawk	Roger M.	University of Arkansas at Little Rock
Hemmati	Mustfa	Arkansas Tech University
Henson	Stanley	Arkansas Tech University
Hinck	Larry	Arkansas State University
Hirschi	Dean	University of Central Arkansas
Hite	Maxine R.	
Hlass	Lisa J.	U.S. Corps of Engineers
Hodges	Howard	University of Arkansas at Little Rock
Hood	William G.	University of Arkansas at Little Rock
Hoyt, Jr.	Arthur	University of Central Arkansas
Huang	Feng Hou	University of Arkansas at Fayetteville
Hudson	M. Keith	University of Arkansas at Little Rock
Huey	Jim	University of Arkansas at Monticello
Hughes	Charles A.	Arkansas State University
Hunkapillar	Paul	Phillips County Community College
Hurlburt	Barry K.	Univ. of Arkansas for Medical Sciences
Hyatt	Philip e.	USDA, Forest Service
Igietseme	Joseph U.	University of Arkansas/Medical Sciences
Ison	Celia	
Jalaluddin	M. D.	University of Arkansas at Pine Bluff
Jansma	Harriet	University of Arkansas at Fayetteville
Jeffries	Douglas L.	University of the Ozarks
Johnson	Ronald	Arkansas State University
Johnson	James E.	University of Arkansas at Fayetteville
Johnson	Michael I.	Nettleton High School
Johnson	Hugh	Southern Arkansas University
Johnson	George P.	Arkansas Tech University
Jones	Suzanne M.	Arkansas State University
Justice	Jay	Ark. Dept. Pollution Control & Ecology
Kannan	Ragupathy	University of Arkansas at Fayetteville
Kaplan	Arnold	
Karlin	Alvan A.	University of Arkansas at Little Rock
Karnes	Mark	The Ross Foundation
Kehler	Philip L.	University of Arkansas at Little Rock
Khan	Shaheen	University of Arkansas at Pine Bluff
Kilambi	Raj V.	University of Arkansas at Fayetteville
Kleve	Maurice G.	University of Arkansas at Little Rock
Kluender	Richard	University of Arkansas at Monticello
Knight	Frank M.	University of the Ozarks
Koeppe	Roger E., III	University of Arkansas at Fayetteville
Komoroski	Richard A.	University of Arkansas/Medical Sciences
Kopper	Randall A.	Hendrix College
Korfmacher	Walter A.	National Ctr. for Toxicological Research
Kral	Timothy	University of Arkansas at Fayetteville
Krause	Paul	University of Central Arkansas
Kreie	Jack C.	Fayetteville Public Schools
Lane	Forrest E.	University of Arkansas at Fayetteville
Lavers	Norman	Arkansas State University
LeJeune	J. K.	Red River Technical College
Lee	Linda A.	Pocahontas Middle School
Lewis	Carolyn	Arkansas Tech University
Lindquist	David	University of Arkansas at Little Rock
Lockhart	J. Mitchell	University of Arkansas at Fayetteville
Lockhart	Brian	University of Arkansas at Monticello
Lortz	David	Univ. of Arkansas at Monticello
Lynch	Thomas J.	University of Arkansas at Little Rock
Mackey	James	Harding University
Malasri	Siripong	Christian Brothers University
Manion	Jerry	University of Central Arkansas
Matthews	H. Michael	Henderson State University
Mazumder	M. K.	University of Arkansas at Little Rock
McAllister	Chris T.	Veterans Affairs Medical Center
McAllister	Russell B.	
McCarty	Clark W.	Ouachita Baptist University (retired)
McConnell	Rose	University of Arkansas at Monticello
McDaniel	V. Rick	Arkansas State University
McLemore	John A.	USDA, Forest Service
McLeod	Paul	University of Arkansas at Little Rock
McMasters	Dennis W.	Henderson State University
McRae	Tammie	National Ctr. for Toxicological Research
Mehta	Rahul	University of Central Arkansas
Mink	Lawrence A.	Arkansas State University
Mitchell	Richard S.	Arkansas State University
Mittelstaedt	Roberta A.	National Center for Tox. Research
Moody	Bonnie	Henderson State University
Moore	Phillip	Arkansas Highway & Transportation Dept.
Moore	Jewel	University of Central Arkansas
Morgans	Leland F.	University of Arkansas at Little Rock
Moss	Linda	
Murphy	Michael	Arkansas State University
Mwasi	Lawrence M.	Univ. of Arkansas at Pine Bluff
Neal	Joseph C.	University of Arkansas at Fayetteville
Nehus	Nathaniel	Ark. Dept. Pollution Conrol & Ecology
Nelson	Thomas	Arkansas Tech University
Nordeen	Russell	University of Arkansas at Monticello
Olson	Larry A.	Arkansas State University
Oosterhuis	Derrick M.	University of Arkansas at Fayetteville
Orr	Clifton	University of Arkansas/Pine Bluff
Owen	Wilbur	University of Central Arkansas
Owens	Don R.	University of Arkansas/Little Rock
Palmer	Bryan D.	Henderson State University
Parsons	Barbara	Univ. of Arkansas at Little Rock
Paulissen	Leo J.	University of Arkansas at Fayetteville
Paulissen	Mark A.	McNeese State University
Peck	John D.	University of Central Arkansas
Pennington	Carlos H.	USAE Waterways Experiment Station
Peterson	Charlotte A.	Veterans Admin. Hospital
Piper	Ed	University of Arkansas
Plummer	Michael V.	Harding University
Pond	Roberta Dee	
Pray	Harold	University of Central Arkansas
Price	Mazo	University of Arkansas at Pine Bluff
Prince	Denver L.	University of Central Arkansas
Quartucci	Gregory M.	Burns & McDonnell
Ramaprasad	S.	University of Arkansas/Medical Sciences
Rasmussen	James A.	Southern Arkansas University
Rettig	Jeff H.	George Washington National Forest
Reynolds	Ruby S.	University of the Ozarks, retired
Rodgers	Michael R.	Ark. Dept. Pollution Control & Ecology
Roe	Amy L.	Nat. Center for Toxicological Research
Roop	Marty	University of Arkansas/Medical Sciences
Root	Peggy	Southern Arkansas University
Rowe	Marsha	Stamps High School
Runge	Steven W.	University of Central Arkansas
Russert-Kraemer	Louise	University of Arkansas at Fayetteville
Sanchez	Rosa I.	University of Arkansas/Medical Sciences
Sanders	Terry A.	Taylor High School
Sealander	John A.	University of Arkansas at Fayetteville
Setliff	Frank L.	University of Arkansas at Littl e Rock
Seward	Larry	John Brown University
Shade	Elwood B.	University of Arkansas at Monticello
Shaikh	Ali U.	University of Arkansas at Little Rock
Shanks	Robert B.	University of Arkansas at Little Rock
Shepherd	William H.	Arkansas Natural Heritage Comm.
Siegel	Samuel	University of Arkansas at Fayetteville
Sifford	Dewey H.	Arkansas State University
Simpson	Kim	Arkansas State University
Slatton	Tom	NLR High School, East Campus
Smith	Edwin B.	University of Arkansas at Fayetteville
Smith	Kimberly G.	University of Arkansas at Fayetteville
Smith, Jr.	Roy J.	U. S. D. A./Univ. of Arkansas
Snow	L. Dale	Louisiana Tech University
Snyder	David G.	University of Arkansas at Monticello
Snyder	W. Sherman	Arkansas Natural Heritage Commission
Speight	Stan	Arkansas State Parks Department
Spiegel	Frederick W.	University of Arkansas at Fayetteville
Standage	Richard W.	U. S. Forest Service
Steele	Kenneth F.	University of Arkansas at Fayetteville
Steward	T. W.	Arkansas State University
Sutherland	Mark	Hendrix College
Sutton	Keith	Hendrix College
Tappe	Phil	University of Arkansas at Monticello
Taylor	William S.	University of Central Arkansas
TeBeest	David O.	Univ. of Arkansas at Fayetteville
Thompson	Lyell	University of Arkansas at Fayetteville
Thurmond	John T.	University of Arkansas at Little Rock
Timmerman	Dan	Arkansas State University
Timmerman	Lorraine	Van-Cove High School
Timmerman	Rudy	Rich Mountain Community College
Trauth	Stanley E.	Arkansas State University
Tull	Dalena	University of Central Arkansas
Tumilson	Renn	Henderson State University
Vere	Victor K.	Arkansas Tech University
Walker	Richard B.	University of Arkansas at Pine Bluff
Walker	Stephen A.	Eastern Kentucky University
Wankum	David L.	University of Arkansas at Little Rock
Weaver	K. Casey	University of Central Arkansas
Webb	Jerry	University of Arkansas at Monticello
Weidemann	G. J.	University of Arkansas at Fayetteville
Wennerstrom	David	University of Arkansas/Medical Sciences
Wennerstrom	Delores	Pulaski Academy
Wilhide	J. D.	Arkansas State University
Williams	Richard A.	University of Arkansas/Monticello
Willis	Rebecca L.	Southern Arkansas University
Wilson, Jr.	Edmond W.	Harding University

LAST NAME	FIRST MI	INSTITUTION
Wolf	Duane C.	University of Arkansas at Fayetteville
Woolverton	Heather L.	University of Central Arkansas
Wright	Robert D.	University of Central Arkansas
Yang	Chia C.	Arkansas Tech University
Yang	Dominic T.	University of Arkansas at Little Rock
York	J. Lyndal	University of Arkansas/Medical Sciences
Young	David A.	Fayetteville Publis Schools
Zachry	Doy L.	University of Arkansas/Fayetteville
Zimmer	Steven W.	Arkansas Tech University

SPONSORING MEMBERS

Bradley	Richard	Univ. of Arkansas at Little Rock
England-Whaley	Lawana	Arkansas State University
Glover	Mattie	University of Arkansas at Pine Bluff
Howick	Lester C.	University of Arkansas at Fayetteville
Sharrah	Paul C.	University of Arkansas at Fayetteville

SUSTAINING MEMBERS

Barton	Harvey E.	Arkansas State University
Bean	Judith A.	Harmony Grove High School
Board	Veryl	Arkansas College
Bollinger	Julia Reed	Arkansas State University
Cleaveland	Malcolm K.	University of Arkansas at Fayetteville
Dale, Jr.	Edward E.	University of Arkansas at Fayetteville
Darsey	Jerry A.	University of Arkansas at Little Rock
Farris	Jerry L.	Arkansas State University
Gandy	Lisa C.	FTN Associates
Hardin	Joyce M.	Hendrix College
Johnston	Perry Max	University of Arkansas at Fayetteville
Marsh	Daniel L.	Henderson State University
McDaniel	Roland E.	FTN Associates, Ltd.
Meyer	Richard	University of Arkansas at Fayetteville
Nisbet	Alex R.	Ouachita Baptist University
Peacock	Lance	The Arkansas Nature Conservancy
Price	Alan D.	Ark. Dept. Pollution Control & Ecology
Rothrock, III	Perry C.	University of Arkansas/Medical Sciences
Sundell	Eric	University of Arkansas at Monticello
Sustich	Andrew T.	Arkansas State University
Watson	Robert L.	University of Arkansas at Little Rock
Wear	James O.	Veterans Admin., No. Little Rock Div.
Willingham	William M.	University of Arkansas at Pine Bluff

LIFE MEMBERS

Anderson	Robbin C.	University of Arkansas at Fayetteville
Bacon	Edmond J.	University of Arkansas at Monticello
Chittenden	David	Arkansas State University
Davis	Leo Carson	Southern Arkansas University
Dilday	Robert H.	University of Arkansas at Fayetteville
Draganjac	Mark	Arkansas State University
England	Daniel R.	Southern Arkansas University
Evans	William L.	University of Arkansas at Fayetteville
Fribourgh	James H.	University of Arkansas at Little Rock
Fry	Arthur	University of Arkansas at Fayetteville
Geren	Collis R.	University of Arkansas at Fayetteville
Giese	John	Ark. Dept. of Pollution Control & Ecol.
Godwin	Walter E.	University of Arkansas at Monticello
Guenter	Joe M.	University of Arkansas at Monticello
Harp	George L.	Arkansas State University
Harp	Phoebe A.	Arkansas State University
Heidt	Gary A.	University of Arkansas at Little Rock
Helms	Ronnie	University of Arkansas at Fayetteville
Jacobs	Carol A.	
James	Douglas	University of Arkansas at Fayetteville
Johnson	Arthur A.	Hendrix College
Mattison	Donald R.	University of Pittsburgh
Moore	Clementine	
Northrop	Gaylord M.	University of Arkansas at Little Rock
Palko	Tom	Arkansas Tech University
Peck	James H.	University of Arkansas at Little Rock
Rapp	Michael W.	University of Central Arkansas
Rickett	John D.	University of Arkansas at Little Rock
Robison	Henry W.	Southern Arkansas University
Saugey	David A.	U. S. Forest Service
Sewell	Stephen A.	University of Mississippi
Speairs	Betty M.	Ouachita Mtns. Biological Station
Speairs	Richard K.	Ouachita Mtns. Biological Station
Templeton	George E.	University of Arkansas at Fayetteville
Tucker	Gary	U. S. Forest Service
Wickliff	James L.	University of Arkansas at Fayetteville
Wiley	Robert W.	University of Arkansas at Monticello

STUDENT MEMBERS

LAST NAME	FIRST MI	INSTITUTION
Adair	Robert E.	University of Arkansas/Fayetteville
Allen	Michelle	University of Arkansas at Little Rock
Bean	Ashley	Hendrix College
Caster	Paul	Univ. of Arkansas at Little Rock
Clark	Mark	Henderson State University
Davis	Angela Wynette	Univ. of Arkansas at Pine Bluff
Ekworomadu	Charles	Univ. of Arkansas for Medical Sciences
Everett	William R.	Univ. of Arkansas at Fayetteville
Fletcher, III	Thomas M.	University of Arkansas/Medical Sciences
Garner	Heath	Arkansas State University
Golden	Kevin D.	University of Arkansas at Fayetteville
Haider	Neena	Arkansas State University
Hansen	Debra	
Heckathorn, Jr.	Walter Dean	University of Arkansas
Huskins	Mark W.	Arkansas Tech University
Isenberg	Seth B.	University of Arkansas at Fayetteville
King	Chris	University of Arkansas
Mayes	Eric	Arkansas State University
McMillan	Pamela J.	University of Arkansas/Medical Sciences
Mintz	Angel	W. R. Grace & Co.
Mooney	Donna	University of Arkansas/Little Rock
Murray	Susan	Arkansas Natural Heritage Comm.
O'Brien	Timothy J.	University of Arkansas/Medical Sciences
Ryan	John M.	University of Arkansas/Fayetteville
Sims	Jay	University of Arkansas/Little Rock
Smith	Jerome V.	Univ. of Arkansas at Little Rock
Weyer	Dora	University of Arkansas at Fayetteville
Wilkins	Phillip K.	Arkansas State University
Williams	Michelle	University of Arkansas/Little Rock
Willis	Jason	University of Arkansas at Little Rock
Withgott	James H.	University of Arkansas at Fayetteville

PROGRAM
Arkansas Academy of Science
Seventy-Seventh Annual Meeting
2-3 April, 1993
Henderson State University at Arkadelphia

Friday, April 2, 1993

Registration	Garrison Activity Center 1st floor lobby
Executive Committee	Dawson Room, 2nd floor West
First Business Meeting	Auditorium, 1st floor West
Exhibits-Refreshments	Hallway, 2nd floor South

Paper Sessions

Biomedical	Cabe Room, 2nd floor South
Vertebrate Zoology	Ross Room, 2nd floor West
Botany	Wilson Room, 2nd floor South
Organic Chemisty and Biochemistry	Room D209, 2nd floor West
Physics, Math, Geology, Engineering	Galloway Room, 2nd floor South
Banquet	Banquet Hall, 2nd floor South
Speaker: Mr. Richard Hoover Title: *"The Unseen World"*	Auditorium, 1st floor West

Saturday, April 3, 1993

Registration	Garrison Activity Center 1st floor lobby
Exhibits-Refreshments	Hallway, 2nd floor South
Second Business Meeting	Auditorium, 1st floor West
Science Education Committee Meeting	Jones Room, 1st floor Center

Paper Sessions

Inorganic-Physical Chemistry	Room D209, 2nd floor West
Physics, Engineering	Galloway Room, 2nd floor South
Aquatic and Environmental Biology	Wilson Room, 2nd floor South
Vertebrate Zoology	Ross Room, 2nd floor West
Invertebrate Zoology	Ross Room, 2nd floor West
Microbiology and Molecular Biology	Cabe Room, 2nd floor South
Science Education	Room D209, 2nd floor West

Friday D202, Saturday L217

SECTION PROGRAMS

*Undergrad **Grad Students

Friday, April 2, 1993

BIOMEDICAL

Chair: Clifton Orr, University of Arkansas at Pine Bluff

*Sensitization of Human Multiple Transitional Cell Carcinoma Cells to Cisplatin by Anguidine. Sedrick C. Rice, Angela W. Davis, Mattie M. Glover and Clifton Orr, Department of Biology, University of Arkansas in Pine Bluff, AR.

*Sensitization of Human Multiple Transitional Cell Carcinoma Cells to Platinum Anticancer Drugs by Anguidine. Miriam M. Glass, Jacqueline A. Potter, Sedrick C. Rice, Mattie M. Glover and Clifton Orr, Department of Biology, University of Arkansas at Pine Bluff, AR.

*Differentiation of Dimethyl Sulfoxide (DMSO) Treated Cells into Granulocytic Cells as Detected by Immunophenotyping and Flow Cytometry. Angela W. Davis and E. Timm, Jr., Department of Biology, University of Arkansas at Pine Bluff, AR and Roswell Park Cancer Institute, Buffalo, NY.

*Effects of Ephedrine Isomers and Their Oxazolidines on Locomotor Acitivity in Rats. Lance M. Williams, Lawrence D. Fitz and Richard B. Walker, Chemistry Department, University of Arkansas at Pine Bluff, AR.

*Long-Term Follow-Up of Atrial and Ventricular Electrograms and Their Correlation with Chronic Capture Thresholds. Jeffrey B. Marott, J. E. Val-Mejias, (Bruce Haggard). Hendrix College, Conway, AR and Wichita Institute for Clinical Research, Inc., Wichita, KS.

Potential Impacts of the Use of Female Condoms on the incidence of HIV Infections in U.S. R. R. Gorforth and S. A. Goforth, Computer Systems Engineering, University of Arkansas at Fayetteville and Holt-Krock Clinic, Fort Smith, AR.

VERTEBRATE ZOOLOGY

Chair: J. D. Wilhide, Arkansas State University

Distribution of the Paleback Darter, *Etheostoma pallididorsum*, an Ouachita Mountain endemic. Mitzi G. Pardew, Betty G. Cochran and William R. Posey II, U.S. Forest Service, Ouachita National Forest, Mt. Ida and Glenwood, AR, Henderson State University, Arkadelphia, AR.

New Distributional Records for Arkansas Sturgeons. Thomas M. Buchanan, Henry W. Robison and Ken Shirley, Department of Biology, Westark Community College, Fort Smith, AR, Department of Biological Sciences, Southern Arkansas University, Magnolia, AR and Arkansas Game and Fish Commission, Little Rock, AR.

Changes in the Arkansas Fish Fauna From 1988 to 1993. Henry W. Robison, and Thomas M. Buchanan, Southern Arkansas University, Magnolai, AR, Westark Community College, Fort Smith, AR.

Distribution of the Mole Salamander, *Ambystoma talpoideum* (Urodela: Ambystomatidae), in Arkansas with Notes on Paedomorphic Populations. Stanley E. Trauth, Betty G. Cochran, David A. Saugey, Williams R. Posey and Wesley A. Stone, Department of Biological Sciences, Arkansas State University, State University, AR, U.S. Forest Service, Caddo Ranger District, Glenwood, AR, and U.S. Forest Service, Ouachita National Forest, Jessieville, AR.

Histology of the Caudal Hedonic Glands in the Dark-Sided Salamander, *Eurycea longicauda melanopleura* (Urodela: Plethodontidae). Stanley E. Trauth, Richard D. Smith and Abby Cheng, Department of Biological Sciences, Arkansas State University, State University, AR.

Break

Enlarged Posterior Maxillary Teeth in the Scarlet Snake, *Cemophora coccinea* (Serpentes: Colubridae), Using Scanning Electron Microscopy. Stanley E. Trauth, Department of Biological Sciences, Arkansas State University, State University, AR.

Extralimital Hummingbirds in Arkansas: An Update, Discussion of Key Traits and the Conservation of Individual Birds. William H. Baltosser, E. Perk Floyd, Max D. Parker, Thomas L. Foti and William M. Shepherd, Department of Biology, University of Arkansas at Little Rock, AR, Arkansas Audubon Society, Malvern, AR, Arkansas Natural Heritage Commission, Little Rock, AR.

Unhatched Eggs in Nests of Red-Cockaded Woodpeckers. Joseph C. Neal, Warren G. Montague, Claudia F. Bailey and Douglas A. James, Poteau Ranger District, Waldron, AR, and Department of Biological Sciences, University of Arkansas, Fayetteville, AR.

Arkansas Range Extensions of the Eastern Small-Footed Bat (*Myotis leibii*) and Northern Long-Eared Bat (*Myotis septentrionalis*) and Additional County Records for the Hoary Bat (*Lasiurus cinereus*), Silver-Haired Bat (*Lasionycteris noctivagans*), Southeastern Bat (*Myotis austroriparius*) and Rafinesque's Big-Eared Bat (*Plecotus rafinesquii*). David A. Saugey, Daniel R. England, Laura R. Chandler, V. Rick McDaniel, Marsha C. Rowe and Betty G. Cochran, U.S. Forest Service, Ouachita National Forest, Jessieville, AR, Department of biology, Southern Arkansas University, Magnolia, AR, Department of Biology, University of Arkansas at Little Rock, AR, Department of Biology, Arkansas State University, State University, AR, Stamps High School, Stamps, AR, and U.S. Forest Service, Ouachita National Forest, Glenwood, AR.

BOTANY

Chair: James Rasmussen, Southern Arkansas University

Costs and Benefits of Endophyte in Tall Fescue, E.L. Piper and C.P. West, Departments of Animal Science and Agronomy, University of Arkansas, Fayetteville, AR.

Influence of Genotype and Culture Medium on Callus Induction from Tall Fescue Leaves. M.E. McConnel, C.P. West and E.L. Piper. Department of Agronomy and Animal Science, University of Arkansas, Fayetteville, AR.

Effects of Fescue Alkaloids on In Vitro Prolactin Release. T.M. Danard, E.L. Piper, A.S. Moubarak and D.H. Hays, Dept. of Animal Science, University of Arkansas, Fayetteville, AR.

Effects of Selected Allelochemicals on Isolated Mitochondria and Chloroplasts. James A. Rasmussen, Frank A. Einhellig and Angela M. Hejl, Department of Biological Sciences, Southern Arkansas University, Magnolia, AR, Graduate Studies and Research, Southwest Missouri State University, Springfield, MO, and Department of Biology, University of South Dakota, Vermillion, SD.

Effect of Light, Nitrogen, and Water Management on Rice (*Oryza sativa*) Tolerance to Fenoxaprop. Roy J. Smith, Jr., Aurora M. Baltazar and Paolo Nastasi, U.S. Dept. Agr., Agr. Res. Serv. and Univ. of Arkansas, Stuttgart, AR.

**Examination of Resistance of Apple Genotypes to Apple Bitter Rot. Yan Shi, Curt Rom and J.C. Correll, Dept. of Hort. and Forestry, and Plant Pathology, Univ. of Arkansas, Fayetteville, AR.

Break

*Stress Induced Protein Changes in Tall Fescue. Robbin L. G. Long, Lance T. Adams, Jerry D. Corley, Alvan A. Karlin, B.L. Parsons, M.G. Kleve and Kurt J. Henle, Department of Biology, University of Arkansas at Little Rock, Department of Medicine and Physiology/Biophysics, University of Arkansas for Medical Sciences and VA Medical Center, Little Rock, AR.

*A Vegetation and Floristic Study on DeGray Lake. Piers Majestyk and Stephanie Modisett, Department of Biology, Henderson State University, Arkadelphia, AR.

Additional Occurrences of the Bog Clubmosses in Southern Arkansas. James R. Bray and Daniel L. Marsh, Department of Biology, Henderson State University, Arkadelphia, AR.

Occurrence of Hybrid Honey Locust (*Gleditsia* X *texana* Sarg.) in Southwest Arkansas. Brian A. Smith and Daniel L. Marsh, Henderson State University, Department of Biology, Arkadelphia, AR.

Botanical Inventory of a Cypress-Tupelo Swamp. Veryl V. Board, Charlotte Allen and Andrea Reeves, Natural Sciences and Mathematics Division, Arkansas College, Batesville, AR.

Leaf and Fruit Variation in the Maple-Leaved Oak, *Quercus shumardii* Buckl. var. *acerifolia* Palmer (Fagaceae). George P. Johnson, Biological Sciences, Arkansas Tech University, Russellville, AR.

George Engelmann's Plant Explorations in Arkansas Territory, 1835. Harriet H. Jansma, Communications Director, Office of University Relations, University of Arkansas, Fayetteville, AR.

BIOCHEMISTRY AND ORGANIC CHEMISTRY
Chair: John Hardee, Henderson State University

*Calcium Uptake and Binding by the Basal Plasma Membrane of the Human Placental Syncytiotrophoblast. Carl Smith, Sid Kammath and Neena Haider, Washington University School of Medicine, Dept. of Pediatrics, St. Louis, MO.

*Preparation of $C_{64}H_{54}F_{24}P_4Ru_2S$. Mandy Prosser, Edmond Wilson and Bill Durham, Department of Chemistry, Harding University, Search, AR and Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR.

*Isolation and Purification of Glutathione Reductase. David C. Limburg and Marsha McNutt, Harding, University, Searcy, AR.

*Oxidation-Bromination of Tetrahydrothiophene. Edward Boone and David Cole, Department of Chemistry, Harding University, Searcy, AR.

The Use of Sodium Percarbonate in the Oxidative Cleavage of alpha-Diketones. Teresa T. Evans and Dominic T. C. Yang, Department of Chemistry, University of Arkansas at Little Rock, AR.

Break

Determiniation of Hammett Pyridine 3-Aza and 4-Aza Replacement Constants by ^1H NMR Studies of Amide Systems. Frank L. Setliff, Nikhil G. Soman and Alan D. Toland, Department of Chemistry, University of Arkansas at Little Rock, AR.

**X-Ray Structure Determination of Oxazolidines Derived from Ephedrine. Lawrence D. Fitz, Ram Kashyap, Lance M. Williams, Lakasa C. Wyatt and Richard B. Walker, Chemistry Department, University of Arkansas at Pine Bluff, AR.

*Effects of Aromatic Ring Substituents on the Rates of Hydrolysis of Oxazolidiness Derived from Ephedrine Isomers and Aromatic Aldehydes. Lakasa C. Wyatt, Lance M. Williams, Lawrence D. Fitz and Richard B. Walker, Chemistry Department, University of Arkansas at Pine Bluff, AR.

A Study of the Reaction Using General-Acid Catalysts in the Reduction of Substituted Benzoquinones by N-Methyl Acridan. Hollie C. Walton and Gaston Griggs, Department of Chemistry, John Brown University, Siloam Springs, AR.

Small Basic Proteins of *Crotalus horridus horridus*; Variation of Compositions and Stucture in Groups and Individuals. Michael L. Merchant and Collis R. Geren, University of Arkansas, Department of Chemistry and Biochemistry, Fayetteville, AR.

PHYSICS, MATH, GEOLOGY, ENGINEERING
Chair: Jules Mollere, Henderson State University

HIV infection and the Intravenous Drug Abuser Community: Analysis and Predictions. Jun Yuan, Daniel Berleant and R. Ron Gorforth, Dept. of Computer Systems Engineering, University of Arkansas, Fayetteville, AR.

Note** User-Interface Coding for the Cern/Geant Nuclear Physics Program. David L. Roetzel and W. J. Braithwaite, Physics and E&I, University of Arkansas at Little Rock, AR.

**Time Projection Chamber's Efficiency, Obtained Using Cern's Geant Code. Charles M. Byrd, Christine A. Byrd and W. J. Braithwaite, Physics/E&I, UALR, Little Rock, AR.

*Monte Carlo Detector Modeling and Display, Using the Cern Library. Christine A. Byrd, Charles M. Byrd and W. J. Braithwaite, Physics/E&I, University of Arkansas at Little Rock, AR.

Break

**Vertebrate Remains from Red River, Southwest Arkansas. Terry A. Sanders, Southern Arkansas University, School of Education, Magnolia, AR.

Sinkhole Excavations in Peccary Cave, Newton County, Arkansas. Leo Carson Davis and Kenneth M. Ball, Department of Physical Sciences, Southern Arkansas University, Magnolia, AR and El Dorado High School, El Dorado, AR.

INORGANIC AND PHYSICAL CHEMISTRY
Chair: James Graham, Henderson State University

A Reevaluation of Distortional Isomerism in $[LWOCI_2]PF_6$. Patrick J. Desrochers and John H. Enemark, Department of Chemistry, University of Central Arkansas, Conway, AR and Department of Chemistry, University of Arizona, Tucson, AZ.

*Gas Phase Reactions of Au^+ with Ethane, Propane and n-Butane. E. E. Ward, W. S. Taylor, L. M. Babcock and T. L. McNeal, Department of Chemistry, University of Central Arkansas, Conway, AR and Department of Chemistry, University of Georgia, Athens, GA.

Reduced Species in Rainfall. David M. Chittenden, Department of Chemistry and Biochemistry, Arkansas State University, State University, AR.

The S-H Stretching Frequencies in Ruthenium Mercaptan Complexes and the Crystal and Molecular Structures of $[CpRu(PPh_3)_2(s\text{-}C_4H_9SH)]BF_4CH_2CI_2$ and $[CpRu(PPh_3)_2(i\text{-}C_4H_9SH)]BF_4CH_2CI_2$. Haengsoon Park, David Minich, M. Draganjac, Joey W. Crump, A. W. Cordes and Elizabeth M. Holt, Department of Chemistry and Biochemistry, Arkansas State University, State University, AR, Department of Chemistry and Biochemisty, University of Arkansas, Fayetteville, AR, and Department of Chemistry, Oklahoma State University, Stillwater, OK.

PHYSICS AND ENGINEERING

Chair: L. Carson Davis, Southern Arkansas University

Summary of K- & L-Shell Ionization by Carbon Ions. Rahul Mehta, Department of Physics, University of Central Arkansas, Conway, AR.

Measurement of NP-Elastic Analyzing Power and Spin Transfer. Heather L. Woolverton, University of Central Arkansas, Department of Physics, Conway, AR.

The Current Effect on the Electron Driven Shock Waves. Mostafa Hemmati, Arkansas Tech University, Physics Department, Russellville, AR.

Pressure Balance at Magnetopause Crossings. Dean Hirschi, University of Central Arkansas, Department of Physics, Conway, AR.

**Superconducting Interconnects for Multichip Modules. R. G. Florence, S. S. Ang and W. D. Brown, Department of Electrical Engineering, University of Arkansas, Fayetteville, AR.

Break

**Sputter Deposition and Thallination of TI-Ba-Ca-Cu-O Superconducting Thin Films. T. H. Dhayagude, S. S. Ang and W. D. Brown, Department of Electrical Engineering, University of Arkansas, Fayetteville, AR.

**Semi-Insulating Polysilicon Hetero- and Isotype Junctions on Silicon. R. M. Ranade, S. S. Ang and W. D. Brown, Department of Electrical Engineering, University of Arkansas, Fayetteville, AR.

*Electrodeposition of Mixed $II\text{-}III_2\text{-}VI_4$ Semiconductor Phases as Potential Thin Film Solar Cell Materials. Robert D. Engelken, Chris Poole, Larry Yu and Gerard Williams, Department of Engineering, Arkansas State University, State University, AR.

*Investigation of Quasi-Nernstian Behavior of Open-Circuit Potentials with Compound Semiconductors Under the NASA Jove Program. Robert D. Engelken, Gerard Williams, Larry Yu and Chris Poole, Department of Engineering, State University, AR.

AQUATIC AND ENVIRONMENTAL BIOLOGY

Chair: Billy Teague, Cooperative Extension Service

Distribution and Population Structure of Freshwatere Mussels (Unionidae) in Lake Chicot, Arkansas. John L. Harris, Pete Rust, Steven W. Chordas III and George L. Harp, Department of Biological Sciences, Arkansas State University, State University, AR.

**The Ichthyofauna of the Village Creek System. Anthony L. Holt and George L. Harp, Department of Biological Sciences, Arkansas State University, State University, AR.

Culvert Modification to Provide Passage for Orangebelly Darters, *Etheostoma radiosum*. Richard W. Standage, Herbert L. Mansbridge and Karen M. Hartman, USDA, Forest Service, Ouachita National Forest, Hot Springs, AR and USDA, Forest Service, Ouachita National Forest, Fourche Ranger Distric, Danville, AR.

**The Fishes of Bayou Meto and Wattensaw Bayou, Two Lowland Streams in Central Arkansas. Walter Dean Heckathorn, Arkansas Fish and Wildlife Cooperative Unit, University of Arkansas, Fayetteville, AR.

Effects of Urban, Nonpoint Source, Stormwater, Runoff on Water Quality, Woodruff Creek, Sherwood, (Pulaski County) Arkansas. Chris A. King, Department of Geology, University of Arkansas, Fayetteville, AR.

Break

Nitrates in Arkansas' Private Rural Water Supplies: Water Sampling and Site Evaluation. Billy Teague, Phil Tacker and Stanley Chapman, University of Arkansas Cooperative Extension Service, Little Rock, AR.

*A Three Year Study of a Cypress-Tupelo Swamp. Veryl V. Board, Charlotte Allen and Andrea Reeves. Natural Sciences and Mathematics Division, Arkansas College, Batesville, AR.

Environmental Analysis of the Coddo River and Its Tributaries: Comparison of Water Quality During 1992 with 1974-75. Kelly L. House, J. D. Bragg, Clark Kuyper, T. Kent Thomas and Renn Tumlison, Garland County Community College, Hot Springs, AR, Henderson State University and Ouachita Baptist University, Arkadelphia, AR.

**Some Effects of Sewage Effluent on an Ozark Stream. Linda E. Moss and George L. Harp, Department of Biological Sciences, Arkansas State University, State University, AR.

Bacteriological and Chemical Quality of Fresh Shrimp Available in Arkansas. Darlene Gentles and J. D. Bragg, Garland County Community College, Hot Springs, AR and Henderson State University, Arkadelphia, AR.

Development of a Low-Level Radioactive Waste Disposal Facility. Greta J. Dicus, Radiation Control and Emergency Management, Arkansas Department of Health, Little Rock, AR.

Ultraviolet Spectra of Acetic Acid, Glycine, and Glyphosate. Rosa McConnell, J. Scott McConnell and Lloyd Hossner, University of Arkansas at Monticello, AR, Southeast Research and Extension Center, Monticello, AR and Texas A&M University, College Station, TX.

VERTEBRATE ZOOLOGY

Chair: Julia Reid Bollinger, Arkansas State University

*Ichthyofauna of a Cypress Tupelo Swamp. Veryl V. Board, Charlotte Allen and Andrea Reeves, Natural Sciences and Mathematics Division, Arkansas College, Batesville, AR.

*Preliminary Home Ranges of an Island Population of Nine-Banded Armadillos *(Dasypus novemcinctus)*. Karen E. Caster, Paul T. Caster and Gary A. Heidt, Department of Biology, University of Arkansas at Little Rock, AR.

*The Effects of Ethanol on Choriovitelline Membrane Vasculature in Chick Embryos. Kay L. Kinneman and Bruce Mendelson, (J. Keith Sutton), Department of Biology, Hendrix College, Conway, AR and Department of Anantomy, University of Arkansas for Medical Sciences, Little Rock, AR.

*Analysis of Convergence in the Structure of Dorsal Guard Hairs of Ecologically Similar Species of Mammals. Connie Baber and Renn Tumlison, Department of Biology, Henderson State University, Arkadelphia, AR.

Analysis of Morphometric Variation in Geographically Isolated Versus Continuous Populations of Plecotus townsendii. Renn Tumlison and Verlan McCool, Department of Biology, Henderson State University, Arkadelphia, AR.

**Home Range of the Southern Flying Squirrel (*Glaucomys volans*) in West-Central Arkansas. Karen D. Stone, Gary A. Heidt and Paul T. Caster, Dept. of Biology, Memphis State University, TN and Department of Biology University of Arkansas at Little Rock, AR.

Mate Choice in Golden Hamster, *Mesocricetus auratus*. Sara M. Hardin, Laura Musolf and Joseph Lombardi, Department of Biology, Hendrix College, Conway, AR.

INVERTEBRATE ZOOLOGY

Chair: Julia Reid Bollinger, Arkansas State University

A Checklist of Phosphorescent Spiders in Arkansas. Peggy Rae Dorris and Robin Owens, Biology Department, Henderson State University, Arkadelphia, AR.

Chironomidae of the St. Francis Sunken Lands in Northeast Arkansas. Betty G. Cochran, Edmond J. Bacon and George L. Harp, U.S. Forest Service, Glenwood, AR, Department of Natural Sciences, University of Arkansas at Monticello, AR and Department of Biological Sciences, Arkansas State University, State University, AR.

*Body Size, Male Aggression, and Male Mating Success in the Cottonwood Borer (*Plectrodera scalator*, Coleoptera: Cerambycidae). Stacie Adams, Steven K. Goldsmith , Zoe Stewart and Angela Trimble, (Keith Sutton), Department of Biology, Hendrix College, Conway, AR and Department of Biology, University of Tulsa, Tulsa, OK.

*Identification of Benthic Invertebrates and Zooplankton From Stomachs of the Ouachita Madtom (*Noturus lachneri*) in the Saline River Drainage, Arkansas. Carolyn N. Lewis, H. Denise Beck, Charlie J. Gagen and Richard W. Standage, Department of Biological Sciences, Arkansas Tech University, Russellville, AR and U.S.D.A. Forest Service, Ouachita National Forest, Hot Springs, AR.

MICROBIOLOGY AND MOLECULAR BIOLOGY

Chair: Ann T. Bragg, Garland County Community College

T Helper Cell Type 1 Activity is Required for Protection Against Chlamydial Genital Disease. J. U. Igietseme, D. M. Magee, T. J. Kincy, D. M. Williams and R. G. Rank, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, AR and University of Texas Health Sciences Center, San Antonio, TX.

Characterization and Mapping of Simian Varicella Virus Transcripts. Nanette J. Gusick, Wayne L. Gray, Thomas M. Fletcher and Carla Y. Pumphrey, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, AR.

Mapping, Sequencing, and Transcriptional Analysis of the Simian Varicella Virus Glycoprotein II Gene. Carla Y. Pumphrey and Wayne L. Gray, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, AR.

A Tomato Fruit Glycine-Rich Protein May be a RNA-Binding Protein. Barbara L. Parsons, Maurice G. Kleve and Autar K. Mattoo, Biology Department, University of Arkansas at Little Rock, AR and U.S.D.A., Argicultural Research Service, Plant Molecular Biology Laboratory, Beltsville Agricultural Research Center-West, Beltsville, MD.

The Role of Ions and Ion Modulators on the Invasion of HELA Cells by *Salmonella typhimurium*, *Shigella flexneri*, and *Listeria monocytogenes*. David Niesel, M. Rachel McDowell and Gaston Griggs, University of Texas Medical Branch, Galveston, TX and John Brown University, Siloam Springs, AR.

Break

*The Preparation of Dual Function Plasmid Vectors for Simultaneous Reporter Gene Screening and Antibotic Resistance Selection in Plant Tranformation. Martha A. Hubbard, Barbara L. Parsons and Maurice G. Kleve, Department of Biology, University of Arkansas at Little Rock, AR.

*Clongin of cDNA for Mouse Lung Glutathion S-Transferase GST 5.7. Michael A. Eckles, Piotr Zimniak, (Mark Sutterland), Hendrix College, Conway, AR and University of Arkansas for Medical Sciences, Little Rock, AR.

**Canela is the Alternate Host of a Heteroecious, Macrocyclic Rust of Horned Rush. D. A. Sadler, R. D. Cartwright and G. E. Templeton, Department of Plant Pathology, University of Arkansas, Fayetteville, AR.

*DNA from the Radiation Resistant Organism *Micrococcus radiodurans* Confers Radiation Resistance to E. coli. Robert Cowherd, James W. Hardin and Thomas J. Lynch, Department of Biology, University Arkansas at Little Rock, AR and Department of Medicine and Biochemistry-Molecular Biology, University Arkansas for Medical Sciences, Little Rock, AR.

The Prevalence of *Borrelia burgdorferi*, the Lyme Disease Spirochete, in Ticks and Rodents in Northeast Arkansas. Kim K. Simpson and Lawrence W. Hinck, Department of Biological Sciences, Arkansas State University, State University, AR.

SCIENCE EDUCATION

Chair: Jane Dunn, Henderson Sate University

Chemistry In Context: Applying Chemistry to Society. Conrad Stanitski, Chemistry Department, University of Central Arkansas, Conway, AR.

Use of a Commercial Interface in the Advanced Chemistry Laboratory. Williams S. Taylor and Paul Krause, Department of Chemistry, University of Central Arkansas, Conway, AR.

Native Plants and Undergraduate Research. William H. Baltosser and Kelly D. Hitt, Department of Biology, University of Arkansas in Little Rock, AR.

Critical Thinking with Botany: Use of Keys, Wagner Trees, and GPDM as Teaching Exemplars. James H. Peck, Department of Biology, University of Arkansas at Little Rock, AR.

A Computer Model for Predicting AIDS Among Intravenous Drug Abusers

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Abstract

Intravenous drug abuse (IVDA) is an important cause of HIV transmission. Computer simulation is one way to understand and predict the spread of HIV infection among IVDAs. We design and simulate HIV infection among IVDAs and the impact of AIDS on this community, and thereby predict future IVDA population, HIV levels, AIDS levels, and AIDS deaths in this group. The HIV to AIDS, and AIDS to Death latencies are described by probability density functions (PDFs) in this model. Factors such as the recruit, quit, and normal death rate of IVDAs, are considered, as well as the infection and removal rates for HIV and AIDS. All these PDFs and rates can be accessed by the user interactively. The impacts of these factors on the IVDA, HIV, and AIDS populations are demonstrated and compared. Discussion of the factors impacting the infection rate provides medical policy makers with useful information.

[1]Authors listed in alphabetical order.

Introduction

Intravenous drug abuse (IVDA) is an important source of HIV transmission. Computer simulation is one good way to analyze and predict the IVDA, HIV, and AIDS populations. There are deterministic models and stochastic ones. Some of them employ sophisticated mathematics and many variables and coefficients. However, due to the complicated human behaviors involved in IVDA it is difficult to accurately describe and predict HIV transmission in the IVDA population. Still, computer simulation provides an efficient way to predict trends, and by research on the factors that affect the disease transmission, can provide helpful information to policy makers in health services and education.

Model Description

Consider IVDA as a community consisting of HIV infected and uninfected populations. IVDA recruits are uninfected but susceptible immediately after they enter the community. Members who are infected with HIV will develop AIDS with a latency described by a certain probability density function (PDF). An AIDS patient will die after another PDF-described latency. Members leave the community because of death, quitting, showing AIDS symptoms, or being isolated for other reasons. We assume that no IVDA exists outside the community, no HIV transmission occurs outside the community, and all AIDS cases are removed from the community immediately. However, HIV infected individuals outside the community will still develop AIDS eventually. The model in graphical form appears in Fig. 1.

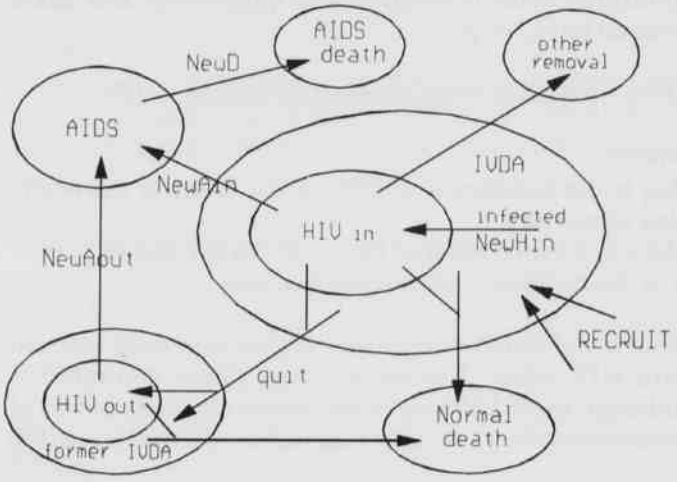

Fig. 1.

Some important characteristics of this model are as follows:

*This is a dynamic model.
*Latencies are defined by PDFs.
*People remain infectious until removed due to AIDS or other reasons.
*No recovery from HIV and AIDS occurs.

Mathematical Model

A dynamic model of the IVDA population is described by Caulkins and Kaplan (1991). That model

considers the recruit and quit rates, giving:

$$dI/dt = c*I^v-\mu*I \quad \text{---(1)}$$

where I is the IVDA population, c and v are the recruit coefficients and μ is the quit rate. We augment this formula by taking two additional factors into consideration: the normal death rate for the IVDA population and the removal of AIDS victims from this population. Then, we have:

$$\Delta I_j = c*I_j^v-(\mu+n)*I_j-NewAin_j \quad \text{---(2)}$$

Where:
I_j is the IVDA population at the beginning of month j.
ΔI_j is the increment in I in month j.
$NewAin_j$ is the AIDS population that is removed from the IVDA population.
c, v are IVDA recruit coefficients.
μ is the IVDA quit rate.
n is the normal death rate.

An epidemiological model is described by Bailey (1957) which models infection rate as proportional to the product of infected and susceptible populations. With the additional consideration of the quit, death and AIDS removal rates, we get:

$$\Delta Hin_j = \alpha*(I_j-Hin_j)*Hin_j-(\mu+n)*Hin_j-NewAin_j \quad \text{---(3)}$$

Where:
Hin_j is the population of HIV in the IVDA at the beginning of month j.
ΔHin_j is the increment of HIV in IVDA for month j.
α is the coefficient of the infection rate.

Hout is the number of former IVDAs who were infected with HIV while they were in the IVDA community. Although these HIVs no longer infect others by means of intravenous drug use, they themselves will develop AIDS:

$$\Delta Hout_j = \mu*Hin_j-n*Hout_j-NewAout_j \quad \text{---(4)}$$

Where:
$Hout_j$ is the population of HIV outside IVDA for the month j.
$\Delta Hout_j$ is the increment in Hout for the month j.
$NewAout_j$ is the number of individuals in $Hout_{j-1}$ who developed AIDS in the past month.

The accumulated AIDS deaths:

$$AD_j = AD_{j-1}+NewD_j \quad \text{---(5)}$$

Where:
AD_j is the accumulated AIDS deaths by the month j.
$NewD_j$ is the AIDS deaths in the month j.
NewAin, NewAout, NewD are associated with probability density functions (PDFs) describing latencies. Suppose the PDF of Fig. 2 describes how the HIVs who are infected in month j are going to develop AIDS over time.

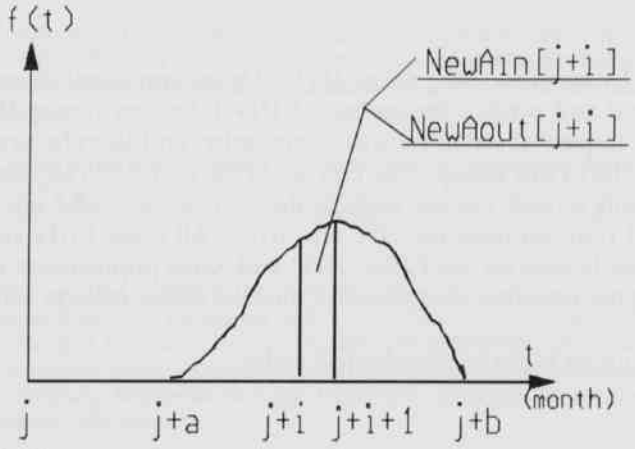

Fig. 2.

Let the number of new HIV cases in month j be called $NewHIV_j$. These HIVs will develop AIDS in the next a to b months according to above PDF. Then this group of HIV will contribute:

$$(\int_i^{i+1} f(t)dt)*NewHIV_j$$

to the newly developed AIDS cases for the month j+i, for a<i≤b.
The NewHIV is calculated in accordance with the first term of equation (3) as:

$$NewHIV_j = \alpha*(I_j-Hin_j)*Hin_j \quad \text{---(6)}$$

However, as HIVs in the IVDA population keep quitting at rate μ, and dying at rate n, in month j+i:

$$\Delta NewAin_{j+i} = (1-\mu-n)^i*(\int_i^{i+1} f(t)dt)*NewHIV_j \quad \text{---(7)}$$

and

$$\Delta NewAout_{j+i} = ((1-n)^1-(1-\mu-n)^1)*(\int_i^{i+1} f(t)dt)*NewHIV_j \quad \text{—(8)}$$

Of course, equations (7) and (8) only show those new AIDS cases in month j+i arising from those individuals who caught HIV in a previous month j. The total NewAin and NewAout in a month, say month p, are accumulated populations contributed by the $NewHIV_q$'s where p-b=<q<p-a, then:

$$NewAin_p = \sum_{q=p-b}^{p-a-1} ((1-\mu-n)^{p-q} * (\int_{p-q}^{p-q+1} * f(t)dt) * NewHIV_q) \quad ---(9)$$

$$NewAout_p = \sum_{q=p-b}^{p-a-1} (((1-n)^{p-q}-(1-\mu-n)^{p-q}) * (\int_{p-q}^{p-q+1} f(t)dt) * NewHIV_q) \quad ---(10)$$

The sum of New Ain_p and $NewAout_p$ gives the total AIDS developed in month p. Similarly, assuming an AIDS onset to AIDS death latency PDF g(t) and ignoring normal death rate because AIDS death latency is relatively short, we have:

$$\Delta NewD_{j+i} = (\int_i^{i+1} g(t)dt) * NewA_j \quad ---(11)$$

where a1=<i<b1, and
$NewA_j = NewAin_j + NewAout_j$
Then the total AIDS deaths in month p is:

$$NewD_p = \sum_{q=p-b1}^{p-a1-1} ((\int_{p-q}^{p-q+1} g(t)dt) * NewA_q) \quad ---(12)$$

From the above discussion, we have built a mathematical model using functions (2), (3), (4), (5), (6), (9), (10), and (12).

The Coefficients

v, μ, n AND c

We choose v=0.5 for the following reasons: v<0 is not meaningful; v>0 because the IVDA population does impact recruitment IVDAs; v<1 because the more the IVDAs, the more the IVDA recruits, but we can not expect that the recruits increases as fast or faster than the number of IVDAs. To compromise, we choose v=0.5. (Later we will see that v has a considerable affect on the model output, thus uncertainity in v should be handled in later work.)

Caulkins and Kaplan (1991) infer μ=0.12, from quit and IVDA population data in years for which such data are available. We therefore use this value.

Berleant et al. (1992) infer the AIDS death rate from the reciprocal of an AIDS survival interval. Similarly, we define the normal death rate as the reciprocal of life expectancy. Assuming a lifetime of 80 years, we get a normal death rate of 1/80. Although IVDAs die faster than average for many causes of death, this is not modeled here. This should probably be modeled in furture work, or at least a sensitivity analysis done to see if it should be modeled.

Assume that before the introduction of AIDS, the size of the IVDA population is approximately constant [Caulkins and Kaplan (1991) make the same assumption], and the incidence of AIDS is zero. Equation (2) then reduces to:

$$\Delta Is = 0 = c * Is^v - (\mu+n) * Is \quad ---(13)$$

Then:

$$c = (\mu+n) * Is/Is^v = (\mu+n) * Is^{1-v} \quad ---(14)$$

ALPHA

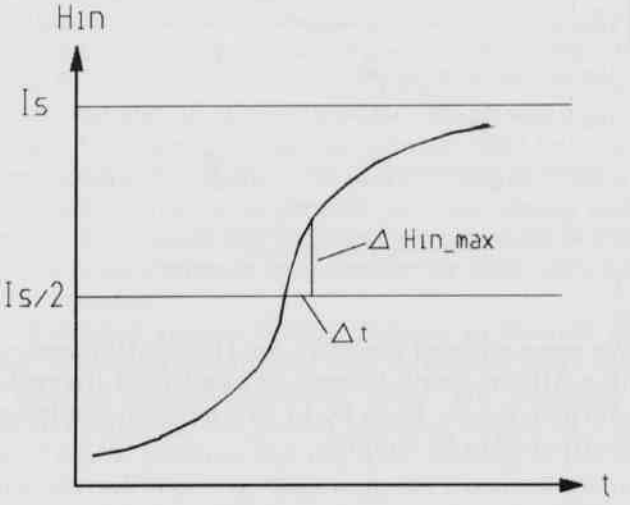

Fig. 3.

As shown in Fig. 3, Hin=α*(Is-H)*H is a logistic curve with the maximum value of (dHin/dt) occuring at Hin=Is/2. Let this dHin/dt equal δ. Then, from equation (6):

$$a * (Is - \frac{Is}{2}) * (\frac{Is}{2}) = \delta * Is$$

which gives:

$$\alpha = 4 * \frac{\delta}{Is}$$

or:

$$\delta = a * \frac{Is}{4}$$

δ is the fraction of Is which is infected with HIV in a unit time (1 month) when the highest infection rate occurs (when Hin=I/s./2). δ is more meaningful than α because δ is independent of Is while α does depend on Is. Therefore, the use of δ makes estimating the infection rate easier. Using δ instead of α in (3) gives:

$$\Delta Hin_j = (4 * \frac{\delta}{Is}) * (I_j - Hin_j) * Hin_j - (\mu+n) * Hin_j - NewAin_j \quad ---(3')$$

We can find the best value for δ by simulating equation (3') for various values of δ, and comparing the resulted trajectories with known historical data. The best value

of δ is that value used in the simulation whose results best match historical data. The best δ we found is 0.24. Results of simulation of this model are demonstrated in Fig. 4.

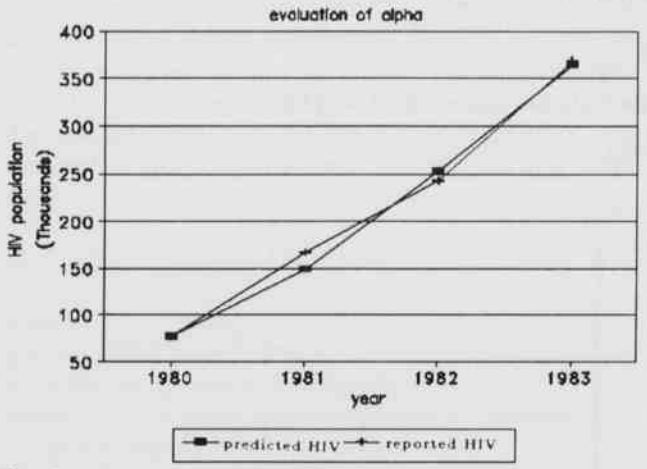

Fig. 4.

PDFS

We approximated the PDFs for HIV-toAIDS latency, and for AIDS-to-death latency, as equilateral triangels. The former ranges from 60 to 140 months, the latter ranges from 12 to 36 months.

Results

IVDA, HIV, and AIDS PREDICTIONS

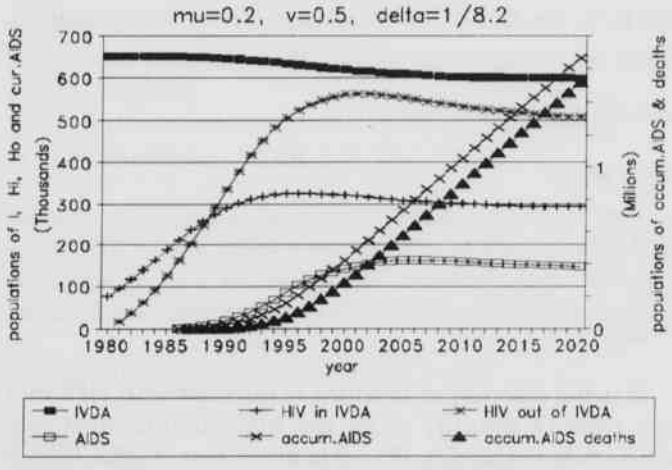

Fig. 5.

In Fig. 5 simulation starts in 1980. IVDA population remains essentially constant until 1988. The fastest HIV increase in IVDA happens when IVDA population is steady and at its highest value. As the susceptible population size decreases, HIV infection slows down. There would be more HIV infection if not for AIDS removal, which first occurs in large numbers in 1987, when HIV in IVDA reaches its estimated maximum of 0.24 million. HIV among former IVDAs follows this trend but more slowly and mildle. AIDS population reaches its maximum of 0.2 million in 2005 and decreases thereafter. By the year 2005, IVDA, HIV and AIDS will be close to their asymptotic equilibria.

IMPACT OF μ, *v* AND δ

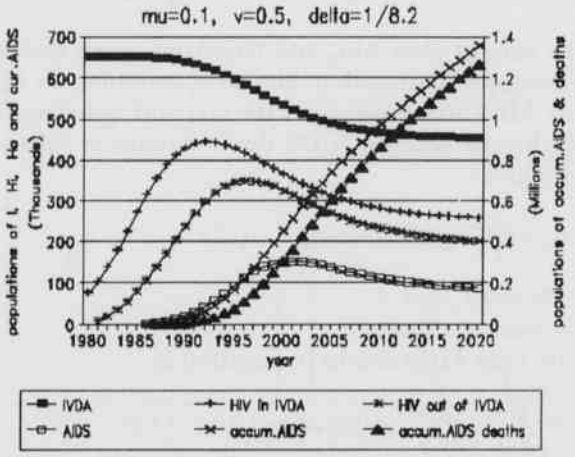

Fig. 6.

In Fig. 6 the quit rate μ is larger. Notice that the HIV outside the IVDA community (who were once inside and are out and inactive now because of quitting or removal by other reasons) has almost an equal population size (or even larger) compared to that of the HIV in IVDA. This is reasonable when the HIVs quit very quickly leading to large buildup of HIV positives among former IVDAs. Further, because relatively few HIV cases remain IVDAs long enough to be removed by developing AIDS, IVDA population is little changed.

In Fig. 7, v=1.0 which means the recruitment rate is more sensitive to the IVDA population. Therefore, as the IVDA decreases, the recruitment decreases faster (compared with the example in Fig. 5). Lower recruitment leads to fewer IVDAs which causes even lower recruitment and so on. By the year 2055, IVDA decreases to about 1/2 of its initial level and the HIV and AIDS

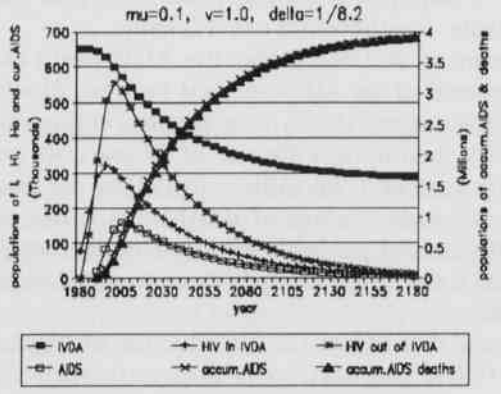

Fig. 7.

decrease asymptotically toward zero.

Figure 8 shows the impact of δ on the result. A higher δ means a higher infection rate. Compared with the corresponding curves in Fig. 5, while the steady state values of IVDA, HIV and AIDS are almost the same, the population of HIV in IVDA increases faster and has a higher maximum value. So does the AIDS population. The reason for the faster increases in HIV and AIDS population is straightforward, and the reason for higher maximum values is the HIV spreads faster and infects more IVDAs before they quit, thus populations of HIV both in and out of IVDA become larger causing higher maximum populations of HIV and AIDS.

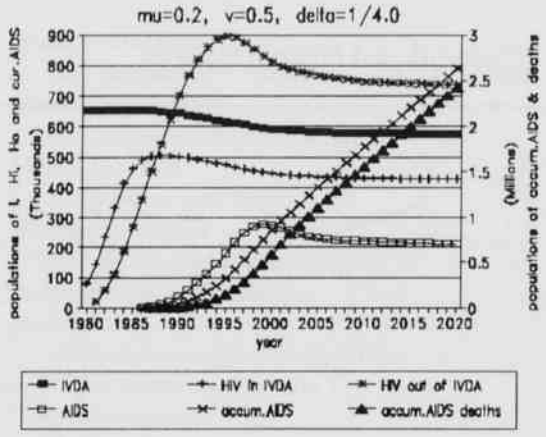

Fig. 8.

Conclusion

It is well known that in the intravenous drug abuse community, HIV spreads easily and quickly. Our results are consistent with that observation. Our results also bear out the conclusion of Caulkins and Kaplan (1991) that AIDS will significantly reduce the IVDA population. However, a critical observation is the apparent fact that the size of the IVDA population will not only remain substantial but will function as reservoir of infection: turnover in this population, and sexual interactions flow between population members and nonmembers, mean a continuous flow of HIV infection from this reservoir to the rest of society. Thus, understanding and dealing with the IVDA/HIV problem is of great social importance.

It is interesting to step back and look at the IVDA/HIV problem from a larger perspective. The HIV virus is known to mutate rapidly. Recent epidemiological work indicates that evolutionary pressures act on pathogens make them more virulent when opportunities to spread are plentiful Ewald (1993). Since needle sharing involves exchange of possible infected blood, it is a highly infective way of spreading HIV (Kaplan, 1989). This suggests that evolutionary pressures facing the HIV virus in the IVDA community will cause it to remain quite virulent or become even more so. Virulence may be measured by the latency between initial infection and AIDS symptoms, with shorter latencies indicating greater virulence. Indeed, it has been found that the virulence of HIV among intravenous drug abusers has continued to be high, whereas among American homosexuals the virus has been becoming less virulent presumably as an adaptive strategy by the virus due to less risky practices among individuals in that group brought about by awareness concerning HIV (Ewald, 1993). Therefore, the IVDA community may serve not only as a reservior of HIV infection, but as a reservoir of particularly virulent HIV virus. In order to reduce not only HIV incidence among IVDAs but also to remove evolutionary pressure on the virus to be virulent, changes in behavior must be encouraged that will reduce the ease of spreading, analogous to the situation that has apparently occurred among homosexuals. Thus proposals like needle exchanging in which addicts could exchange used needles for clean ones merit close attention.

Ecological systems tend to increase in diversity over time. Ecological systems also tend to become more stable as diversity increases (Logofet, 1993). The mutability of the HIV virus and the known presence already of a variety of strains indicates that the virus' diversity is not only high but will increase. This suggests that humankind's relation with the HIV is, unfortunately, a "stable" one and therefore that the HIV problem will likely remain with us into the indefinite future.

Literature Cited

Bailey, N.T.J. 1957. The mathematical theory of epidemics. Charles Griffin & Co., London, pp. 1-32.

Berleant, D., R. Goforth, and **A. Khanna.** 1992. Comparison of simulation with PDFs vs. fuzzy values. Proceedings of the Symposium on Computer Simulation in Industrial Engineering and in the Problems of Urban Development, Mexico City, Society for Computer Simulation.

Caulkins, J.P. and **E.H. Kaplan.** 1991. AIDS impact on the number of intravenous drug user. Interfaces 21 (3):50-63.

Ewald, P.W. 1993. The evolution of virulence. Pp. 86-93 *In* Scientific American, April 1993.

Kaplan, E.H. 1989. Needles that kill: modeling human immunodeficiency virus transmission via shared drug injection equipment in shooting galleries. Reviews of Infectious Diseases, 11 (2):289-295.

Logofet, D.O. 1993. Matrices and graphs: stability problems in mathematical ecology, CRC Press, Boca Raton, FL.

Botanical Inventory of a Cypress-Tupelo Swamp

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Abstract

Collection of plants from a cypress-tupelo swamp located at the eastern border of Independence County was part of a long range plan to document the flora of the county. Efforts were made to determine if the study area would fit the current federal definition of wetlands which requires a periodic or permanent inundation of the soil.

Introduction

This report is part of a three year ecological study of a small cypress-tupelo swamp located in the floodplain of the Black River in eastern Independence County, Arkansas. Bottomland forests with alluvial river swamps were once common throughout the Mississippi Alluvial Delta of Arkansas and several such swamps occurred in the county (Mitsch and Gosselick, 1986). However, much of the floodplains of both the Black and White Rivers in Independence County has been cleared and the land devoted to agriculture. Wooded areas are often restricted to stream banks, low wet areas, and corners of fields. The lower floodplain of the Black River in the county is usually planted with rice, soybeans and sorghum. The rice fields are extensively irrigated with water from the Black River and these irrigation ditches support both woody plants and aquatic plants.

Study Area

Hattie's Brake (Fig. 1) is a small swamp located in the Black River bottom, about four miles northeast of Cord, Independence County, Township 12N, Range 3W, western half of Section 25. It is typical cypress-tupelo swamp which has about 8.1 ha of open water lying within a c-shaped depression bordered by the 220 foot contour on the topographic map. An extension of Milligan Slough carries water into the swamp and there are several small seasonal streams that carry excess water to the Black River about 0.6 m away.

The swamp fits the federal definition of a wetland in the amount of time the swamp is flooded, by the species composition of woody vegetation and the soil type (Field Comm. for Wetland Delineation, 1989). The characteristic soil of much of Section 25 is classified as Forestdale, a silty loam which is poorly permeable and deep (Ferguson et al., 1982). The area is usually flooded annually from the Black River, but some water enters from Old Curia Creek by way of Saltwork and Milligan Sloughs.

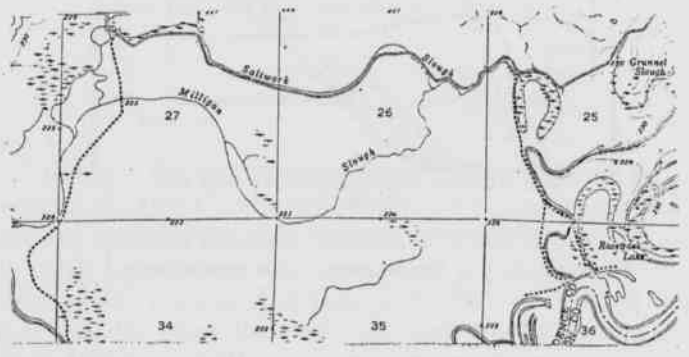

Fig. 1. Topographical Map of Hattie's Brake and Its Environs

Methods and Materials

Plant specimens were identified primarily by the use of the keys in Steyermark (1963). Reed (1986) provides a good list of wetland plants for Arkansas while Smith (1988) provides the best available distributional records of Arkansas plants. Collections of plants were made along the roadsides around the edges of the swamp, in the rice field ditches, and in the low wet areas of Saltwork Slough. Plants collected are preserved in the herbarium of Arkansas College and voucher specimens will be sent to the herbarium at the University of Arkansas.

Results

Table 1 lists plants that have been found in the swamp area that were not identified as occurring in Independence County (Smith 1988). The species composition of woody plants found in Hattie's Brake and its environs are similar to that reported by McKnight et al. (1980)

for alluvial swamps in the Atlantic Coastal Plain and the Mississippi Delta. As expected, the closest correlation is with the Delta. McKnight et al (1980) reported 17 families of trees in the swamps of the Atlantic Coastal Plain and 21 families in the Mississippi Delta. Some 70 species of trees representing 26 families of plants have been identified from Hattie's Brake. Table 1 lists 39 species of plants representing 25 families not previously reported from Independence County.

Table 1. Plants of Hattie's Brake

I. **Anacardiaceae**
- A. *Toxicodendron toxicarium* (Salisb.) Gillis

II. **Asclepiadaceae**
- A. *Asclepias sullivantii* Engelm

III. **Boraginaceae**
- A. *Heliotropium indicum* L.

IV. **Campanulaceae**
- A. *Lobelia appendiculata* A. DC.
- B. *Lobelia cardinalis* L.

V. **Asteraceae**
- A. *Pluchea camphorata* (L.) DC.
- B. *Xanthium strumarium* L.

VI. **Convolvulaceae**
- A. *Convolvulus arvensis* L.

VII. **Brassicaceae**
- A. *Cardamine pensylvanica* Muhl. ex Willd
- B. *Iodanthus pinnatifidus* (Michx.) Britt.
- C. *Rorippa palustris* (L.) Besser

VIII. **Cucurbitaceae**
- A. *Sicyos angulatus* L.

IX. **Fagaceae**
- A. *Quercus falcata* Michx. var. pagodifolia Ell.

X. **Hydrophyllaceae**
- A. *Hydrolea uniflora* Ref.

XI. **Lamiaceae**
- A. *Lamium purpureum* L.

XII. **Lenguminosae**
- A. *Gleditsia aquatica* Marsh.
- B. *Trifolium campestre* Schreb.
- C. *Wisteria frutescens* (L.) Poir.

XIII. **Loganiaceae**
- A. *Spigelia marilandica* L.

XIV. **Malvaceae**
- A. *Hibiscus laevis* Allioni

XV. **Oleaceae**
- A. *Ligustrum sinense* Lour.

XVI. **Polygonaceae**
- A. *Polygonum hydropiperoides* Michx.
- B. *P. lapathifolium* L.
- C. *P. punctatum* Ell.
- D. *P. scandens* L.

XVIII. **Rosaceae**
- A. *Crataegus crus-galli* L.

XVIII. **Scophulariaceae**
- A. *Gratiola virginiana* L.

XIX. **Solanaceae**
- A. *Physalia virginiana* P. Mill
- B. *Solanum eleagnifolium* Cav.

XX. **Ulmaceae**
- A. *Celtis laevigata* Willd.
- B. *Ulmus crassifolia* Nutt.

XXI. **Urticaceae**
- A. *Boehmeria cylindrica* (L.) Sw.

XXII. **Azollaceae**
- A. *Azolla mexicana* Presl.

XXIII. **Alismataceae**
- A. *Echinodorus cordifolius* (L.) Griseb.

XXIV. **Cyperaceae**
- A. *Rhynchospora corniculata* (Lam.) Gray

XXV. **Lemnaceae**
- A. *Lemna minor* L.
- B. *Spirodela polyrrhiza* (L.) Schleid.
- C. *S. punctata* (G.F.W. Meyer) Thompson
- D. *Wolffia brasiliensis* Weddell

Bald cypress and water tupelo are interspersed evenly through the open water of the swamp and extend up Milligan Slough. There is a low area in the southern part of Section 25 that holds water for extended periods of time and supports a number of very large specimens of both cypress and tupelo trees.

The drier areas support a large population of trees including 14 species of oaks and four species of hickories. Roadsides contain some of the driest soils and are characterized by four species of elms including the late summer fruiting *Ulmus crassifolia* Nutt. Sweetgum, mulberry, persimmon and ashes are scattered throughout Section 25. Three maples have been identified in the environs of the swamp. Both the water and honeylocusts are present and their spines are commonly found on the ground.

There are relatively few emergent aquatics associated with the swamp even though they are present in both irrigated rice fields and in the shallower portions of Saltwork Slough. However, the swamp supports populations of floating aquatics involving species of Lemnaceae and Azollaceae. These species include *Spirodela polyrrhiza* (L.) Schleid., *Lemna minor* L., *Wolffia brasiliensis* Weddell and *Azolla mexicana* Presl.

Clearings, tracks and roadsides often provide space enough for light to reach the ground and this encourages a heavy undergrowth. This undergrowth includes both

poison ivy and oak, greenbriar of several species, grapes and two species of Cucurbitaceae including *Sicyos angulatus* L.

The milkweeds are repesented by *Asclepias sullivantii* Engelm. Terrestrial ferns are not abundant, but the grape fern, *Botrychium biternatum* (Sav.) Underwood was seen. There are probably more species of Asteraceae than any other family, with the ragweeds and species of *Bidens* being represented by the most species.

The rice fields adjacent to the swamp support a greater diversity of aquatic plants than the swamp. The roadside ditches and shallower sections of Saltwork Slough contain several species of Polygonaceae including *Polygonum lapathifolium* L. and *P. pensylvanicum* L. In the fields, *Sphenoclea zeylandica* Gaertn. represents a species recently found in the area. The Pontederiaceae are represented by two species of *Heteranthera*: *H. limosa* (Sw.) Willd. occurring in both a blue - and a white - flowered form and H. *reniformis* R & P.

Saltwork Slough supports a number of species of Alismataceae including *Echinodorus cordifolius* (L.) Griseb. and *Sagittaria latifolia* Willd. The open water is partly covered by *Ludwigia peploides* (H.B.K.) Raven while *L. alternifolia* L. is found in slightly drier areas. *Hibiscus laevis* Allioni and H. *lasiocarpos* Cav. occur around the edges of the slough.

Conclusions

Hattie's Brake and its environs represent an uncommon ecosystem for Independence County. The herbaceous and woody plants listed in Table 1 supports the USF&WS definition of a wetlands which requires the presence of hydrophytic vegetation. The occurrence of this cypress-tupelo swamp represents an extension of the Mississippi Alluvial Plain into the county thereby increasing the biodiversity of the area.

Acknowledgements

Our appreciation is expressed to Mr. Jim Barnett, representing the owners, and Mr. Don Coleman, who leases the land, for their cooperation in allowing us entry into the study area. The study has been supported by funds from the Natural Sciences and Mathematics Division and by a faculty development grant from Arkansas College.

Literature Cited

Ferguson, Dick V., J.S. Lowerance and **C.E. McFadden.** 1982. Soil Survey of Independence County Arkansas. USDA Soil Conservation Service. Washington, D. C. 148 pp.

Field Interagency Committee for Wetland Delineation. 1989. Federal Manual for Identifying and Delineating Jurisdictional Wetlands. U.S. Corp of Engineers, USEPA; USF & WS and USDA Soil Conservation Service, Washington, D.C. Cooperative Technical Publication. 78 pp.

McKnight, J.S., D.D. Hook, O.G. Langdon and **R.L. Johnson.** 1980. Flood Tolerance and Related Characteristics of Trees of the Bottomland Forests of the Southeastern United States (Pp. 87-160). *In* J.K. Clark, and J. Benforado. 1981. Wetlands of Bottomland Hardwood Forests. Elsevier Scientific Publishing Co. New York, NY.

Mitsch, W.J. and **J.G. Gosselink.** 1986. Wetlands. Van Nostrand Reinhold. New York, NY. 539 pp.

Reed, Porter B., Jr. 1964. Wetland Plants of the State of Arkansas. U.S. Department of Interior; U.S. F & W S St. Petersburg, FL. 31 pp.

Smith, E.B. 1988. An Atlas and Annotated List of the Vascular Plants of Arkansas. Second Edition. Kikko Copies. Fayetteville, AR. 489 pp.

Steyermark, J.A. 1963. Flora of Missouri. Iowa State University Press. Ames, IO. 1728 pp.

A Multiple Sample Cryostat for the Determination of Superconductor Properties

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Abstract

Cryostats which are currently used to characterize the properties of superconductors between 4 K and 100 K are primarily single sample devices. The purpose of this paper is to present an instrument design which can hold up to five (5) one cm. diameter samples at a stable temperature (± 0.1 K) within the above range specified while measurements of the sample properties are made.

Introduction

The characterization of potential superconducting materials requires an instrument which can maintain a stable temperature within the superconductor's electromagnetic transition range (usually between 4 K and 77 K). Such devices, called Cryostats, use liquid helium, LHe, and/or liquid nitrogen, LN_2, to provide a cold reservoir above which the sample temperature is varied. Commercial Cryostats, while providing excellent temperature stability, are usually single sample devices which cost between $10,000 and $20,000 (Van Sciver, 1986). The object of this project is to design and build a multi-sample Cryostat for superconductor evaluation for a total cost of $5,000.

The design of the Cryostat began with a survey of the pertinent literature regarding the design and construction of commercial cryostats, from both practical and theoretical considerations. The various methods of varying temperature were explored with the additional constraints of producing an economical accessible multi-sample device.

Design

Heat Load and Vacuum Considerations.--The Cryostat is composed of two concentric dewers (Fig. 1), a liquid helium, LHe, reservoir which is surrounded by a reservoir of liquid nitrogen, LN_2. The LN_2, at 77 K, reduces the radiational heat load from room temperature into the more expensive liquid helium by three orders of magnitude since this load is proportional to the fourth power of the absolute temperature (White, 1968). The relation is given by Stephan-Boltzmann's law and is of the form

$$Q_r=\sigma(T_2^4-T_1^4)/V,$$

where σ is the Stephan-Boltzmann constant ($5.67 \times 10^{-4} W/m^2-K^4$), and V is the view factor which relates the areas and emmisivities of surface two as seen by surface one.

To further reduce heat loss, the volume external to each of these dewers is evacuated to decrease the conductive heat loss of the gases and to reduce the losses due to external condensation on the LN_2 dewer. By lowering the pressure, the distance a molecule travels before colliding with another (called the mean free path) increases to the point where the dominant method of thermal energy exchange is due to collision between the remaining gas molecules and the dewer walls. Pressure reductions of 10^{-4} torr correspond with a mean free path of 100 cm (Rose-Innes, 1973), which is much less than the interwall distance of the dewers. Because the pressure in these areas is determined by the statistical interactions of the molecules (molecular flow), the ports to the external diffusion pump must be made as large as possible. This provides a large cross-sectional area through which the particles may pass and be trapped.

The location of welds and venting of blind threaded holes also becomes important when considering molecular flow. If a weld between two plates is on the pressurized side of a vacuum-pressure interface, as shown in Fig. 2, the molecules within the seam will only 'see' the face of the seam to pass through and the time to pump down to sufficient vacuum increases (Green, 1986).

The diameter of the tubes which are used to fill the cryogens into their respective dewers are important in that if the tube is sufficiently small (less than 2.5 cm) and is long (over 30 cm) the tube may develop powerful low frequency vibration due to the thermosiphoning of vapor from the dewer to the atmosphere (Green, 1986). Fill tubes are made as short as possible to eliminate these

problems.

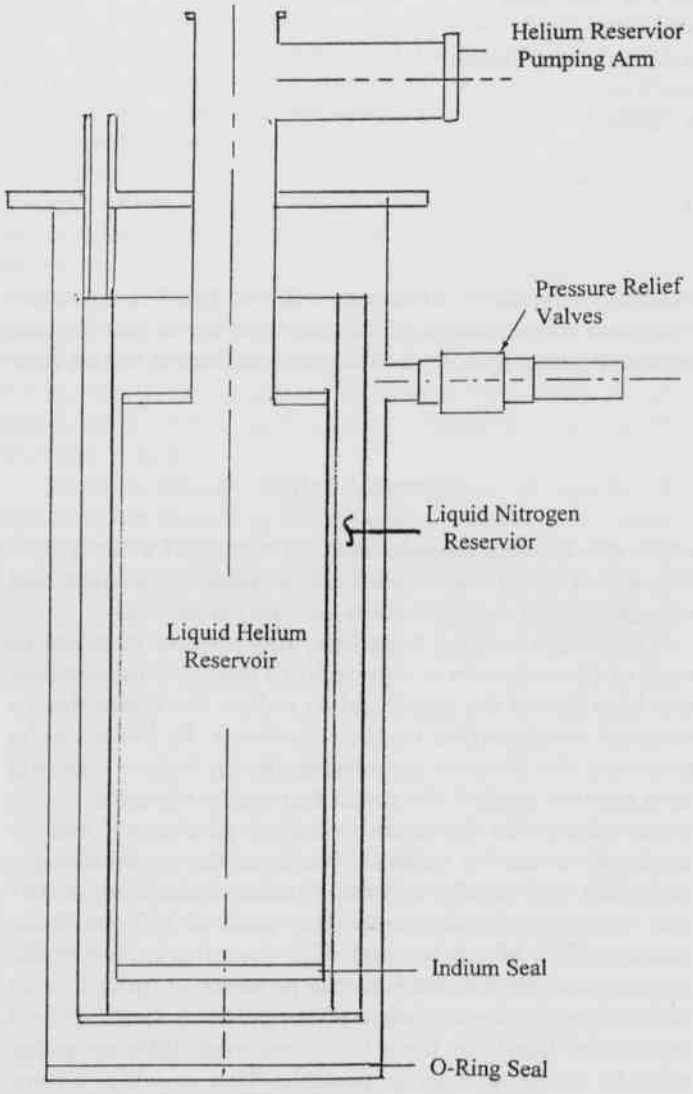

Fig. 1. Cryostat Dewer

A safety pressure relief valve is mounted on the outer shell of the Cryostat in case of a leak of one of the cryogens into the vacuum jacket. Upon contact with the room temperature wall of the jacket, the cryogen would expand and increase the pressure which might destroy the Cryostat.

Stainless steel was chosen as the material from which the Cryostat would be constructed since it does not outgass in a vacuum, has low thermal conductivity (16 W/m-K), high yield strength (130 kpsi), and is readily welded. Where a stainless steel plate is to be welded to a length of tube to form a dewer, a groove is cut into the plate to half of its thickness, as shown in Fig. 2. This reduces the stress on the weld by creating a much smaller area across which thermal shrinkage occurs during dewer cooling as the pure tensile weld stress is reduced by the cantelever thus created (Barron, 1966). Additionally, a seating groove is cut into the tube to minimalize shear stresses on the weld.

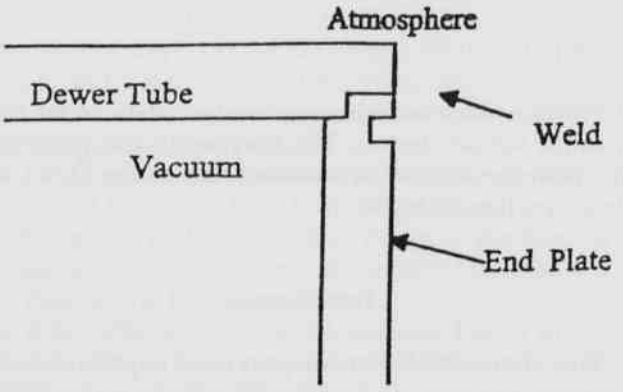

Fig. 2. Welded connection between dewer tube and end plate showing improper weld location.

Temperature Variability.--Superconducting samples may be placed directly in contact with either the LN_2 or the LHe to determine their properties at those temperatures, although the energy involved in measuring the resistance of the material will tend to raise its temperature above that of the surrounding cryogen. If the sample holder is made to be in good thermal contact with the cryogen, then any heat added to the holder will quickly be passed to the liquidfied gas and will not significantly raise the temperature of the sample. To vary the temperature of the sample then, the sample must first be cooled to cryogenic temperatures, and then the sample should be thermally isolated from the cryogen. Any heat which is subsequently added will primarily raise the temperature of the sample and not be wasted in boiling the liquified gas (Holma, 1981).

An exchange gas method (Obert et al., 1982) for temperature variation was chosen to modify the temperature of the sample, as shown in Fig. 3. As seen in this figure, the gas exchange insert fits into the Cryostat helium dewer fill tube. The temperature of the sample is varied by indirectly coupling the sample to the LHe by varying the pressure of helium gas in the sample compartment. When the pressure of the gas is high (760 torr), the thermal link between the LHe and the sample is good and the sample approaches 4 K. As the pressure in the sample compartment is reduced, it becomes thermally isolated

from the cryogen and the sample temperature can be raised by a small heater imbedded in the sample mounting block. A thermocouple mounted on the sample block is used to determine the average block temperature.

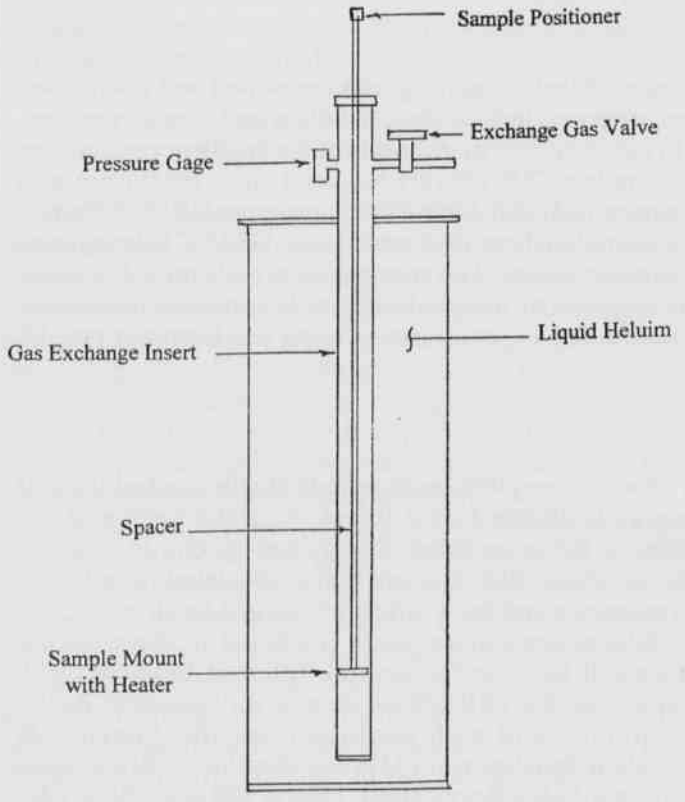

Fig. 3. Gas Exchange Insert for Cryostat

Cryostat Operation.--Initial loading of the Cryostat begins with purging of the device with nitrogen gas, which flushes the room air and concomitant moisture from the walls of the instrument. The evacuation valve is then attached to a rotary pump and the pressure is 'roughed in'. Once the pressure is reduced to approximately 10^{-2} torr, the diffusion pump is started and the pressure is reduced to 10^{-4} torr. The evacuation valve is closed and the LN_2 is the introduced into the dewer. This brings the temperature of the device down to 77K, whereupon the LHe is siphoned from a storage dewer. The LHe cryopumps the pressure in the vacuum jacket to 10^{-6} torr which provides an ideal storage environment. Estimates on the heat load indicate that the instrument will require 15 liters of LN_2 for initial cooling.

Multiple samples which are to be introduced into the Cryostat are prewired and screwed to the sample mount. The samples are cleaned to remove any oils which would outgas under reduced pressure, preventing the attainment of a sufficient vacuum. Next, the samples are mounted in the gas exchange insert, which is flooded with room temperature helium gas. The entire insert is precooled in the nitrogen dewer and then the insert is placed in the Cryostat LHe fill tube where it cools to 4K. After equilibrating, measurements on the samples are taken to determine if any of the samples are superconducting. The insert pressure is then lowered by pumping which thermally isolates the sample mount from the Cryostat sufficiently to begin heating the sample block for temperature manipulation.

Literature Cited

Barron, R. 1966. Cryogenic Systems. McGraw-Hill. New York. 255 pp.

Green, G. W. 1986. The Design and Construction of Small Vacuum Systems.Chapman and Hall, London. 99 pp.

Holma, J. P. 1981. Heat Transfer. McGraw-Hill, New York. 132 pp.

Obert, W. Coupland, J. R., Hammond, D. D., Cook, T. and **Harwood, K.** 1982. Advances in Cryogenic Engineering. Vol. 25, p. 293.

Rose-Innes, A. C. 1973. Low Temperature Laboratory Techniques, English Universities Press, London. 118 pp.

Scott, R. B. 1963. Cryogenic Engineering, Met-Chem Research Inc., Boulder. 98 pp.

Siegel, R. and **Howel, J. R.** 1981. Thermal Radiation Heat Transfer, McGraw-Hill, New York. 52 pp.

White, G. K. 1968. Heat Transfer. Oxford University Press, London. 233 pp.

Van Sciver, S. W. 1986. Helium Cryogenics. Plenum Press, New York. 85 pp.

Monte Carlo Detector Modeling and Display, Using the Cern Library

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Abstract

Detectors for high energy nuclear physics experiments are being modeled using programs developed and maintained at CERN, the European Organization for Nuclear Research. These programs include data handling and display routines, as well as those using random-sampling Monte Carlo techniques to calculate energy depositions for high energy particles as they pass through the various parts of the detector system. The complete CERN library has been imported for use with our Workstation computers in a multiple user environment. The enormous CERN Monte Carlo program GEANT (French for GIANT) tracks the progress of a particle through a detector on a simulated event-by-event basis. GEANT is being used to predict energy loss in materials using several different energy-loss assumptions. The energy loss in a silicon slab is calculated for charged particles at moderately relativistic momenta. The response of these calculations is known to result in an asymmetric energy deposition in silicon. Predicted responses are scheduled for examination using test beams at two different accelerator facilities.

Introduction

Some members of the High Energy Nuclear Physics Cluster at the University of Arkansas at Little Rock (UALR) are participating in Experiment Number 35 and Experiment Number 49 in the experimental North Area at CERN, the European Organization for Nuclear Research in Geneva, Switzerland. These experiments are referred to as NA35 and NA49, respectively. In addition, UALR has been granted independent institutional status in the approved Solenoidal Tracking experiment (STAR) at the Relativistic Heavy Ion Collider (RHIC) located at Brookhaven National Laboratory.

Researchers at UALR are eligible to use the CERN program library, developed and supported by CERN staff, due to their involvement with experiments NA35 and NA49 at CERN.

During the last year, UALR has imported the complete CERN library for use with our Digital Equipment Model 5000 (DEC-5000) Workstation computers. To assure backward compatibility, we maintain, as does CERN, old, new and production versions of each program on a common platform for simultaneous access by a variety of users. The principal UALR efforts are concentrated on two CERN programs: the Monte Carlo detector-modeling program, GEANT, and the display and data manipulation program PAW [Physics Analysis Workstation].

GEANT tracks the progress of a particle through a detector on an event-by-event basis (Geant, 1992). Each step uses known interaction probabilities and random choices to determine subsequent events.

Each subsequent event is individually tracked until its energy is depleted or it leaves the active region of the detector being modeled. Energy loss spectra in semiconductor silicon detectors are being calculated for a variety of momenta and for a variety of charged particles.

Silicon detector response predicted in these calculations will be tested at several different momenta with pions from the TRIUMF accelerator in Vancouver, British Columbia, and with protons from the Alternating Gradient Synchrotron (AGS) accelerator at Brookhaven National Laboratory. These efforts will test the predictions of GEANT under varying energy-loss assumptions.

Materials and Methods

For our work with the NA35 and NA49 experiments at CERN, as well as with the STAR collaboration, we are utilizing software packages from the CERN-program library on our DEC-5000 workstations to simulate the progress of charged particles on an event-by-event basis as they pass through semiconductor silicon detectors.

GEANT is one of the general purpose Monte Carlo codes for modeling the response of detectors to individual charged particles and, subsequently, to each charged particle's spallation products. This versatility accounts for its popularity in the High Energy Physics community.

UALR is using the Monte Carlo program GEANT to model pion and proton energy deposition in slab silicon at several different momenta to test the accuracy of GEANT predictions for these charged particles. This effort is assessing the accuracy of quantitative predictions

of energy loss within semiconductor silicon detectors, which is relevant to identifying particle types using semiconductor silicon.

In addition, we are using GEANT to predict energy losses for electrons, pions, kaons, and protons passing through multiple slabs of active silicon detector material with thicknesses between 250 and 300 μm. Then we calculate the expected energy-loss separation between these particles passing through the multiple layers of silicon using two different methods.

Results and Discussion

The STAR instrument at RHIC, like most high energy detectors, uses a known magnetic field to bend charged particles in order to compute the momentum of each from the curvature of each measured path. Thus, separation of charged particle types into distinct groups involves identifying some distinguishing property at fixed momentum. One candidate for this distinguishing property is dE/dx, the rate of energy loss per unit distance in a detector (Bichsel, 1988). This rate is proportional to the amount of energy loss in a thin detector.

PAW is used to produce Fig. 1, which shows an energy loss distribution for charged pions incident on a 300-micrometer silicon detector, where each pion has a momentum of 300 MeV/c (where 1 MeV = 1.6×10^{-13} Joules and the speed of light $c = 3 \times 10^8$ meters/sec). The distribution shown in Fig. 1 is asymmetric, slightly favoring higher energy losses, which are induced by nearly head-on collisions of incident pions with electrons in the silicon. Asymmetric "tailing" in the energy loss distribution makes it difficult to separate different particle types, at fixed momenta, on the basis of their energy losses in a thin silicon detector.

However, since a head-on collision with an electron is an improbable event, a charged particle passing through multiple detectors is unlikely to have a nearly head-on collision in more than one of the detectors. To facilitate separation of particle types, two methods have been reported for reducing the asymmetry in the energy loss for the same charged particle. One method of particle-type separation employs a 'truncated mean method' (Schukraft, 1992), where, in multiple measurements, he throws away the most energetic events and averages the remainder. The other employs a "maximum-likelihood method" (Cramer, 1992) which makes use of all the data, but is most time consuming.

Detector design is carried out using codes like GEANT, which compute energy losses in a detector on a Monte Carlo basis, from probability distributions for the rate of energy loss, dE/dx. Options within GEANT use different strategies to calculate dE/dx for charged particles. The two most commonly used options are based on the Landau distribution (Landau, 1956), originally developed for collisions of fairly relativistic electrons with electrons. A more complicated approach is still being developed at CERN for the GEANT source code based on the Vavilov distribution (Vavilov, 1957; Schorr, 1974). Our present efforts are aimed at calculating the energy loss for pions and protons at fixed momenta using the various energy loss assumptions available in GEANT, so these predictions can be compared with data taken with test beams at the TRIUMF accelerator in Vancouver and the AGS accelerator at Brookhaven National Laboratory.

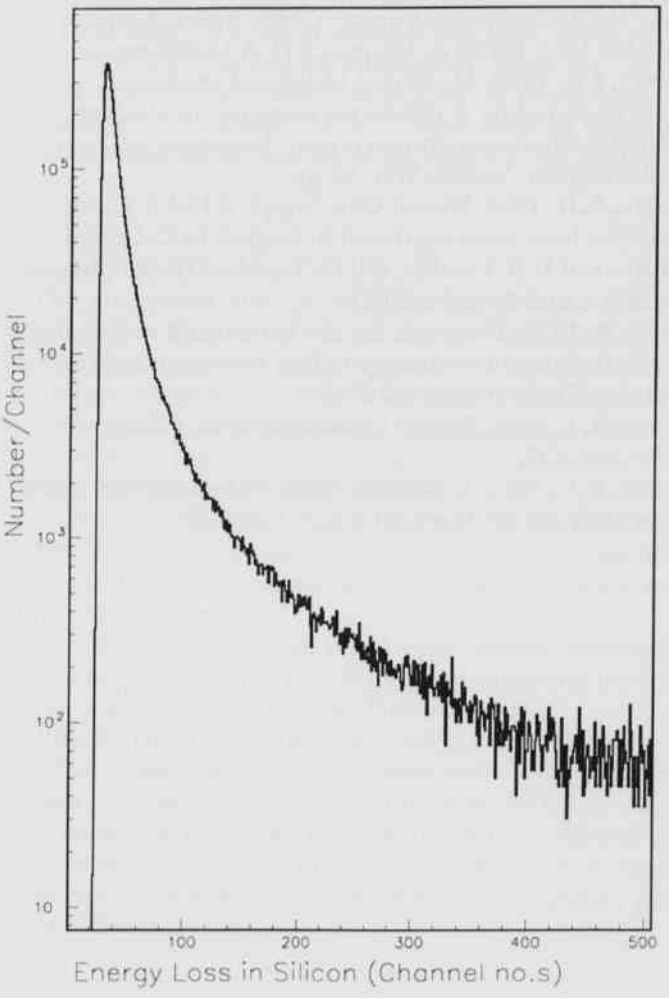

Fig. 1. Semi-logarithmic plot of the frequency distribution of 5 million 300-MeV/c pions, incident on a 300-micrometer slab of silicon, simulated using a Landau-distribution energy loss option in GEANT.

Acknowledgements

This work acknowledges the help of the STAR Collaboration and the NA35 and NA49 Collaborations. This work acknowledges G. Douglas Mauldin, David L. Roetzel and Morgan T. Burks for calculations of energy loss, and Dr. Marcus D. Gabriel for help with the DEC-5000s. This work was supported in part by the U. S. Department of Energy and the Arkansas Science and Technology Authority.

References Cited

Bichsel, H. 1988. Straggling in thin silicon detectors. Reviews of Modern Physics 60:663-669.

Geant 1992. Geant user's guide. CERN internal report. CERN Data Division, Geneva, CH. 3.15:365 pp.

Cramer, J.G. 1992. Maximum likelihood analysis of dE/dx sampling at relativistic energies. In Nuclear physics laboratory annual report. University of Washington, Seattle, WA. 56 pp.

Landau, L.D. 1956. Nuovo Cim. Suppl. 3:15-17. These articles have been reprinted in English *In* Collected Papers of L.D. Landau, ed. D. Ter Haar (New York: Gordon and Breach, 1965).

Schorr, B. 1974. Programs for the landau and vavilov distributions and the corresponding random numbers. Comp. Phys. Comm. 7:215-224.

Schukraft, J. 1992. Private Communication. CERN, Geneva, CH.

Vavilov, P.V. 1957. Ionization losses of high energy heavy particles. Soviet Physics J.E.T.P. 5:749-751.

Time Projection Chamber's Efficiency, Obtained Using CERN's Geant Code

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Abstract

Geometrical acceptance and reconstruction of tracks have been carried out for a Time Projection Chamber (TPC) used in Experiment NA35: the 35th experiment in the North Area of the Super Proton Synchrotron (SPS), located at the European Organization for Nuclear Research (CERN). NA35 used the SPS at CERN to produce 6.4 TeV beams of ^{32}S for central collisions with Au nuclei. The TPC modeling effort used a modified version of CERN's Monte Carlo program GEANT, which simulates the response of the NA35 TPC to output from CERN's primary event generators. GEANT was used to simulate three-dimensional pixel data in the same format as data taken by direct readout of the TPC. These simulated data were stored on magnetic tape and processed using the TPC analysis and reconstruction program TRAC. Analysis of these simulated data allowed a calculation of the efficiency of the TPC, to within about 1%, by comparing the output of TRAC with the known input from GEANT. Also, reconstructed events from GEANT were used to eliminate false tracks and to determine systematic errors in track position and momentum in data taken by NA35 in the Spring of 1992.

Introduction

If we could travel back in time to fractions of microseconds after the Big-Bang, we would find the universe to be extremely hot and dense. At these high energy densities (>3 GeV/fm^3 or >4.8 x 10^{35} Joules/m^3), quarks and gluons, normally trapped inside hadrons, escape and move freely within this high energy density region. This deconfinement of the quarks is predicted to occur as a Quark-Gluon Plasma. An experimental group at the University of Arkansas at Little Rock is investigating matter at energy densities where a Quark-Gluon Plasma is expected to form.

Ultra-relativistic nucleus-nucleus collisions produce similar energy densities as those calculated for a fraction of a microsecond after the Big-Bang. Nuclei accelerated to kinetic energies about 100 times their rest mass are moving at nearly the speed of light, with their length contracted by a factor of 100 in their direction of motion. The high energy densities following each central collision results in the possibility of exciting a Quark-Gluon Plasma.

It would be very interesting to "observe" the Quark-Gluon Plasma as it expands and cools, first creating kaons, then pions, as the temperature progressively cools. Similar interferometric techniques to those used by astronomers for measuring the sizes of nearby stars are applied to the nuclear domain to measure the size and duration of quark-gluon "hot spots" produced in the aftermath of each central ultra-relativistic nucleus-nucleus collision, where each "hot spot" decays into hundreds of charged pions (Cramer, 1991).

The enormous energy densities required to form a Quark-Gluon Plasma necessitate the use of huge particle accelerators and very large detectors weighing several thousands of tons. The Time Projection Chamber (TPC) is indispensable in determining, simultaneously, momenta of each of the hundreds of secondary particles. The TPC provides excellent geometrical acceptance, good resolution and "automatic" digital data representing the x, y, and z coordinates of each individual secondary particle track produced following a central collision between two ultra-relativistic nuclei.

Even if a TPC meets all the design criteria, systematic errors may occur in the process of reconstructing particle tracks from experiment data. This makes it necessary to determine the TPC's track reconstruction efficiency in order to make corresponding corrections. Furthermore, since we are primarily interested in hadrons which originate from the hot spots located around the vertex, we must determine criteria to eliminate tracks which result from either track reconstruction errors or secondary particles (Roland, 1922b).

Materials and Methods

The TPC uses collections of instrumented cathodes (called Pads) to collect ionization left by the passage of charged particles through the gas-filled TPC volume. A 100-200 V/cm field is used to sweep the electrons to anode chains where they are accelerated, causing an

avalanche multiplication of electrons. The x and y coordinates of each particle trajectory are given by the pad locations, while the z coordinate is determined from the electron drift time. The pad charge is amplified and enters the digital sampling process through one of several hundred thousand detector channels. The data are then stored on magnetic tapes for later analysis.

Although the intrinsic sensitivity of a TPC is ultimately determined by the instrument's physical design parameters and data acquisition electronics, the response of the detector depends on the data analysis software. Such physical characteristics as pad plane design determine the optimal performance of the detector, while the effectiveness of the design depends on the processing and interpretation of detector signals (Jones and Rai, 1991). The usefulness of the information provided by the acquisition electronics will depend on the ability of the analysis software to reconstruct tracks from hits, identify particles, determine momentum and other particle characteristics (Roland, 1992a).

The response of the TPC is determined using simulated events produced by FRITIOF, which generates particles using the Lund model (Anderson et al., 1982) for string fragments. These events are then used by the GEANT detector simulation program to create input for the data analysis software (Geant, 1992). The efficiency of the TPC is determined by comparing the track analysis from the reconstruction software to the original tracks produced by the GEANT simulation code (Bloomer et al., 1992). In addition to improving the efficiency and accuracy of the TPC track reconstruction algorithms, the simulation chain produces the necessary data required to determine selection criteria for tracks, further reducing error by allowing a prefiltering of tracks which were produced outside of the collision vertex region.

Results and Discussion

The determination of track reconstruction efficiency and the setting of vertex selection criteria are important to the correlation analysis. This effort reduces the number of specious tracks generated outside the collision vertex by decays or by secondary particle production without appreciably reducing the efficiency of primary tracks needed to extract particle source sizes. Also, two particle correlation analysis (Gyulassy and Harlander, 1991) requires excellent momentum resolution and particle identification, established by the present work on TPC track reconstruction efficiency.

The NA35 TPC TRAC algorithms were found to have reconstruction efficiencies of better than 95% for charged particles at normal track density. When track density was increased by a factor of 3 in the simulated data sets, the efficiency was found to drop less than 5%. In addition, rejection of events more than 6.0 mm from the collision vertex resulted in less than a 4% reduction in reconstruction efficiency, while reducting background events by over 35%. These results were found by comparing simulated data with the experimental NA35 data taken in the Spring of 1992.

The same simulation tools used in detector design are being used in refining the data analysis software, an application of equal importance.

Acknowledgements

This work acknowledges the NA35 and NA49 Collaborations. Special thanks is given to Dr. Guenther Roland, of the Nuclear Physics Institute, Frankfurt, Germany, for this invaluable help. This work was supported in part by the U.S. Department of Energy and by the Arkansas Science and Technology Authority.

Literature Cited

Anderson, B., G. Gustafson, T. Sjöstrand, G. Ingelman, O. Mansson and **I. Holgerson.** 1982. Soft gluons, baryon-antibaryon production and low transverse momentum physics in the Lund model. (Pp. 21-26) *In* Proceedings of the XII International Symposium on Multiparticle Dynamics. Univ. Notre Dame. NSF. et al., Notre Dame, IN, USA.

Bloomer, M.A., P.G. Jones and **I.M. Sakrejda.** 1992. Evaluation of the performance of the STAR TPC for detecting p+p collisions at RHIC. STAR Note 57. Computer file. Relativistic collisions group. Lawrence Berkeley Laboratory, Berkeley, CA.

Cramer, J.G. 1991.Analysis of multiparticle Bose-Einstein correlations in ultrarelativistic heavy ion collisions. Phys. Rev. C. 43:2798-2807.

Geant 1992. Geant user's guide. CERN internal report. CERN Data Division, Geneva, CH. 3.15: 365 pp.

Gyulassy, M. and **M. Harlander.** 1991. Elastic tracking and neural network algorithms for complex pattern recognition. Comp. Phys. Comm. 66:31-46.

Jones, P.G. and **G. Rai.** 1991. The STAR TPC pad response function. STAR Note 33. Computer file. Relativistic collisions group. Lawrence Berkeley Laboratory, Berkeley, CA.

Roland, G. 1992a. Status of the NA35 TPC analysis software. In NA35 internal report. Institut für Kernphysik, Frankfurt, FRG. pp. 12-14.

Roland, G. 1992b. TPC data reconstruction algorithms. NA35 internal report. Institut für Kernphysik, Frankfurt, FRG. p. 5.

Larval Chironomids of the St. Francis Sunken Lands in Northeast Arkansas

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Abstract

Sixty semi-annual collections (August 1987-July 1988) were made from 30 stations by sampling each station twice for 1.5 man-hours with an aquatic dipnet. Larval chironomids were mounted on slides and identified at 400-1000 magnifications using a Leitz Dialux 20 EB microscope. A survey of the aquatic macroinvertebrates of the St. Francis Sunken Lands in northeast Arkansas revealed 36 taxa of Order Diptera, Family Chironomidae. The taxa were used to evaluate the general health of the aquatic environment. Stations that were located within the least disturbed areas, which were old river channels and oxbows, contained the highest number of organisms and greatest diversity of taxa per station. Stations that were located either in channelized ditches with intense agricultural activities in the watershed or in the St. Francis Lake area, where the homogeneous substate restricted habitat diversity, contained fewer numbers of organisms and taxa per station.

Introduction

The physiographically unique Sunken Lands lie along the eastern edge of Crowley's Ridge in northeast Arkansas within the St. Francis River flood plain. The Sunken Lands range from 1.0-7.5 km wide and extend approximately 50.0 km from the Arkansas-Missouri state line in eastern Greene County through Craighead into Poinsett County. The St. Francis River meanders through the Sunken Lands in a braided series of oxbows, sloughs, natural channels and channelized ditches. The Sunken Lands are characterized by seasonally flooded bottomland hardwood and agriculturally inhospitable terrain, a natural refugium for flora and fauna which were more broadly distributed in the Mississippi Alluvial Plain before man's alteration of habitat became so severe. This unique ecosystem also provides a source of filtration and renewal to the ground water reserve (Cochran and Harp, 1990).

Methods and Materials

Chironomids of this study were collected from August, 1987, through July, 1988, during a survey of the aquatic macroinvertebrates of the St. Francis Sunken Lands. Sixty semi-annual collections were taken from 30 stations by sampling each station twice for 1.5 man-hours with an aquatic dipnet. Organisms were stored in 70 percent ethanol (Cochran and Harp, 1990).

Slides of larval chironomids were prepared for identification according to methodology described by Beckett and Lewis (1982), using CMCP-9 low viscosity colorless mountant manufactured by Polysciences. Identifications were made at 400-1000 magnifications using a Leitz Dialux 20 EB microscope. Some chironomid larvae were identified to species groups because of the lack of larval associations with adults and the complexity of many species groups. Larval chironomids were identified to the lowest possible taxonomic level using primarily the keys provided by Oliver et al. (1978), Simpson and Bode (1979), Bode (1983), Simpson et al. (1983), Wiederholm (1983), and Coffman and Ferrington (1984).

Morisita's idex of community similarity was calculated using the ECOLOGICAL ANALYSIS VOL. 3-PC program of Oakleaf Systems, Decorah, IA.

Results and Discussion

Seven hundred forty-eight specimens were identified representing 37 taxa at the ranks of genus, species and species group. Subfamilies Tanypodinae and Orthocladiinae were represented by eight taxa each and Chironominae by 21, disposed in two tribes, with 15 in Chironomini and six in Tanytarsini (Table 1).

Each of the 30 stations was assigned to one of four associations, distinguished by distinct physical factors, within the river channels and the immediate watershed. The Old River Channel-Oxbow Association (OROA) contained ten stations at the upper region of the study area where the watershed typically consisted of climax vegetation of cypress, oaks and willows, with the natural river channels largely intact (Cochran and Harp, 1990). The mean number of taxa/station at the OROA was 33% greater than that for the entire study area and the mean

Journal of the St. Francis Basin, Northeast Arkansas

Table 1. Chironomidae expressed as number collected/association (OROA, old river channel-oxbow; CDPA, channelized ditches-point source pollution; SFLA, St. Francis Lake-open water; CDAA, channelized ditchs-intense agriculture) and study area total (SAT).

	OROA	CDPA	SFLA	CDAA	SAT
Ablabesmyia mallochi (Walley)	11	0	0	3	14
Ablabesmyia parajanta Roback	3	0	1	1	5
Clinotanypus sp.	18	0	8	2	28
Coelotanypus sp.	7	0	0	0	7
Larsia sp.	5	1	1	2	9
Procladius sublettei Roback	6	0	4	0	10
Tanypus neopunctipennis Sublette	0	0	1	2	3
Thienemannimyia sp.	1	0	0	0	1
Cricotopus bicinctus (Meigen)	7	1	0	3	11
Eukiefferiella potthasti group	8	1	0	1	10
Hydrobaenue sp.	14	0	0	11	25
Nanocladius rectinervis (Kieffer)	1	0	0	0	1
Orthocladius sp.	198	1	4	95	298
Rheocricotopus robacki (Beck and Beck)	0	0	0	1	1
Thienemanniella xena Roback	1	0	0	0	1
Tvetenia bavarica group	51	0	0	0	51
Chironomus decorus group	38	0	5	13	56
Chironomus riparius group	0	0	0	3	3
Cladotanytarsus sp.	0	0	0	1	1
Cryptochironomus fulvus group	3	1	1	7	12
Dicrotendipes neomodestus (Malloch)	15	0	1	16	32
Endochironomus nigricans (Johannsen)	4	0	0	12	16
Endochironomus subtendens (Townes)	0	0	1	0	1
Glyptotendipes lobiferus (Say)	4	0	0	9	13
Parachironomus abortivus (Malloch)	0	0	0	4	4
Paratanytarsus sp.	0	0	1	2	3
Phaenopsectra dyari (Townes)	9	1	5	4	19
Polypedilum convictum (Walker)	1	0	0	0	1
Polypedilum illinoense (Malloch)	31	5	1	21	58
Polypedilum scalaenum (Schrank)	1	0	3	3	7
Pseudochironomus sp.	0	0	7	0	7
Rheotanytarsus sp.	1	0	0	0	1
Rheotanytarsus exiguus group	3	0	4	2	9
Stictochironomus sp.	1	0	0	2	3
Tanytarsus glabrescens group	5	0	0	1	6
Tanytarsus querlus group	12	0	2	6	20
Tribelos jucundum (Walker)	1	0	0	0	1
Total Individuals	460	11	50	227	748
Total Taxa	29	7	17	26	37

Table 2. Mean number of taxa and individuals per station for each association and study area (SA).

	OROA	CDPA	SFLA	CDAA	SA
Taxa	8.3	3.5	5.2	5.3	5.6
Individuals	46.0	5.5	10.0	17.5	19.8

number of individuals/station was 57% greater (Table 2). This association exhibited the greatest diversity of chironomid taxa and the greatest number of individuals within the study area (Table 1). Organisms found to occur exclusively or predominantly in the OROA and occupy a wide range of habitats were: *A. mallochi, A. parajanta, Larsia* sp., *T. glabrescens, T. querlus* and *T. jucundum*. Other taxa exclusive to or predominating in the OROA but preferring slow moving waters with soft sediments and/or sandy-muddy substrate were: *Clinotanypus* sp., *Coelotanypus* sp., *Thienemannimyia* sp., *T. bavarica* and *T. xena*, which is considered to be sensitive to organic pollution (Simpson and Bode, 1979; Wiederholm, 1983; Hudson et al., 1990).

The Channelized Ditches-Point Source Pollution Association (CDPA) contained only two stations, at one of which no chironomids were collected. Due to the small sample size this association was not evaluated further.

The five stations in the St. Francis Lake-Open Water Association (SFLA) occurred in relatively undisturbed areas (Cochran and Harp, 1990). In contrast to the river channels and channelized ditches, the SFLA represented an almost lentic habitat with a homogeneous substrate. Allochthonous organic material typically formed a mat-like substrate of decomposing leaf matter of up to 0.5 m deep, which would be an effective deterrent to many organisms.

The mean number of taxa per station here was 8% less than that for the entire study area and 37% less than that for the OROA. The mean number of organisms per station was only 50% of that for the entire study area and 78% less than that for the OROA (Table 2). Two taxa that occurred exclusively in the SFLA were *E. subtendens* and *Pseudochironomus* sp. (Table 1).

The Channelized Ditches-Intense Agriculture Association (CDAA) was represented by 13 stations typically located in the lower region of the study area (Cochran and Harp, 1990). The stations of this assocation were the most altered by man's intervention, having been subjected to channelization of the river, removal of riparian trees and shrubs, and drainage from agricultural activities. Although not definable as pollution, such habitat alterations may be just as detrimental and/or limiting to the biota.

The mean number of taxa per station at the CDAA was

comparable to that of the SFLA (2%>) and the study area (6%<), but was 33% less than for the OROA. The mean number of organisms per CDAA station was 43% greater than for the SFLA, 12% less than for the study area, and 62% less than for the OROA (Table 2).

Taxa exclusive to or most abundant in the CDAA were: *Paratanytarsus* sp., *E. nigricans*, *G. lobiferus* and *P. abortivus*. The first may be a pest in water, while the last three listed exhibit a tolerance of most toxic and organic wastes and are found to occur in habitats with high nutrient and organic waste levels in channelized sections of slow-moving rivers (Simpson and Bode, 1979; Wiederholm, 1983; and Hudson et al., 1990).

Morisita's index of community similarity, also known as Morisita's index of overlap (Horn, 1966), is based on Simpson's index of dominance and has the desirable characteristic of being little affected by sizes and diversities of samples. It ranges from 0 (no similarity) to 1.0 (identical) and compares the probability that individuals randomly drawn from each of the two communities will be the same species to the probability of randomly selecting a pair of specimens of the same species from one of the communities. Community similarity is not considered significant unless the Morisita's index is 0.7 or above (William J. Matthews, per. comm.).

Morisita's index of community similarity for the OROA, CDPA, SFLA, and CDAA was 0.384 or less for any of the two associations, indicating little similarity. The community dissimilarities are largely explained by the differences in habitat types (natural river channels, lentic/lake and channelized ditches). Only five taxa (14%) were collected within all the associations.

Acknowledgement

This project was sponsored in part by the Arkansas Game and Fish Commission (AFGC) through a research grant intiated under the Dingell-Johnson Sport Fish Restoration Act (Dingell-Johnson Project F-42).

Special thanks are extended to AGFC Law Enforcement Officer Elvis Poe, Jr. and to M. Doug Fletcher for their invaluable collecting assistance.

The authors also express appreciation to J. Alan Clingenpeel for his assistance with the statistical calculations and slide preparations.

Literature Cited

Beckett, D.M. and **P.A. Lewis.** 1982. An efficient procedure for slide mounting of larval chironomids. Trans. Amer. Micros. Soc. 101:96-99.

Bode, R.W. 1983. Larvae of North American *Eukiefferiella* and *Tvetenia* (DIPTERA: CHIRONOMIDAE). Bull. N.Y. St. Mus. No. 452:1-40.

Cochran, B.G. and **G.L. Harp.** 1990. The aquatic macroinvertebrates of the St. Francis Sunken Lands in northeast Arkansas. Proc. Ark. Acad. Sci. 44:23-27.

Coffman, W.P. and **L.C. Ferrington, Jr.** 1984. Chironomidae. Pp. 551-652, *In* An introduction to the aquatic insects of North America. 2nd ed. (R. W. Merritt and K.W. Cummins, eds). Kendall/Hunt Publishing Co., Dubuque, IA.

Horn, H.S. 1966. Measurement of "overlap" in comparative ecological studies. Amer. Natur. 100: 419-424.

Hudson, P.L., D.R. Lenat, B.A. Caldwell and **D. Smith.** 1990. Chironomidae of the Southeastern United States: A checklist of species and notes on biology, distribution, and habitat. US Fish. Wildl. Ser., Fish. Wildl. Res. 7. 46 pp.

Oliver, D.R., D. McClymont and **M.E. Roussel.** 1978. A key to some larvae of Chironomidae (Diptera) from the Mackenzie and Porcupine River watersheds. Fish and Marine Serv. Tech, Report No. 791:1-73.

Simpson, K.W. and **R.W. Bode.** 1979. Common larvae of Chironomidae (Diptera) from New York State streams and rivers with particular reference to the fauna of artificial substrates. Bull. N.Y. St. Mus. No. 439:1-105.

Simpson, K.W., R.W. Bode and **P. Albu.** 1983. Keys for the genus *Cricotopus* adapted from "Revism der Gattung *Cricotopus* van der Wulp and ihrer Verwandten (Diptera, Chironomidae)" by M. Hirvenoja. Bull. N.Y. St. Mus. No. 450:1-133.

Wiederholm, T. (ed.) 1983. Chironomidae of the Holoarctic region. Keys and diagnoses. Part 1. Larvae. Ent. Scand. Suppl. 19:1-457.

Sputter Deposition and Thallination of Tl-Ba-Ca-Cu-O Superconducting Thin Films

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Abstract

Thallination techniques used for the fabrication of sputter-deposited $Tl_2Ba_2CaCu_2O_x$ and $Tl_2Ba_2Ca_2Cu_3O_x$ superconducting thin films were investigated. Differences in elemental composition of precursor Ba-Ca-Cu-O sputtering targets were found to yield different superconducting phases. Thallination conditions which yielded transition temperatures as high as 122 K for samples annealed in air are described. Finally, reactive ion etching of films using a mixture of chlorine and argon gases is discussed.

This research was funded by E-Systems and supported in part by an equipment grant from the Kurt J. Lesker Company.

Introduction

The Tl-Ba-Ca-Cu-O superconducting system has received considerable attention due to the inherent high temperature transition, T_c, and critical current density J_c, of some of its phases. The $Tl_2Ba_2Ca_2Cu_3O_{10}$ (2223) phase compound has the highest T_c (R=0) at 127 K (Sheng and Hermann, 1988; Sheng et al., 1988). Superconducting Tl-Ba-Ca-Cu-O thin films can be fabricated by sputtering, laser ablation or evaporation of Ba-Ca-Cu-O from a single target followed by a complicated high-temperature annealing sequence in an excess Tl-vapor pressure ambient (Qui and Shih, 1988; Sheng et al., 1988; Shah et al., 1990). Interest in this material is high because the potential commercial applications of Tl-Ba-Ca-Cu-O thin films in passive and active electronic devices are enormous (Superconducting Technologies, Inc., private communication).

The properties of Tl-Ba-Ca-Cu-O superconducting thin films are greatly influenced by the elemental composition of the precursor Ba-Ca-Cu-O target and the post-deposition thallination conditions of the Ba-Ca-Cu-O precursor films. It has been shown that their T_c values are primarily determined by the number of copper layers involved in the perovskite slabs (Martin et al., 1990). Under optimum conditions, the T_cs for (2212) phase films are around 100 K with a J_c of greater then 10^5 A/cm^2 and, for (2223) phase films, are around 122 K with J_c of about $5x10^4$ A/cm^2 on <100>-oriented magnesium oxide (MgO) substrates.

In addition to the fabrication of high-quality films, it is important to develop appropriate microfabrication techniques and junction fabrication technology to realize high-T_c electronic devices. The patterning of thin superconducting films has been demonstrated using.

In this paper, a two-step fabrication technique for the fabrication of high T_c (2212) phase and (2223) phase superconducting films is reported. The etching of precursor films using reactive ion etching (RIE) with a chlorine and argon plasma is discussed.

Materials and Methods

Ba-Ca-Cu-O precursor films were RF magnetron sputtered onto polished <100>-oriented MgO substrates in a modified Perkin-Elmer PE 2400 sputtering system using either $Ba_2Ca_2Cu_3O_x$ or $Ba_2Ca_{2.3}Cu_3O_x$ targets. All sputter depositions were performed in an argon atmosphere at room temperature. The chamber pressure during deposition was maintained constant at 10 mT. The target-substrate separation was constant at 10 cm. The best precursor films were obtained when the substrates were placed directly beneath the target. The RF power densities were optimized for the $Ba_2Ca_2Cu_3O_x$ and $Ba_2Ca_{2.3}Cu_3O_x$ targets. Deposition times were varied to obtain film thicknesses of 4500 to 8000 Å. Film thicknesses and deposition rates were determined using a Sloan Dektak surface profilometer.

Post-deposition thallination of the precursor films was accomplished by placing the films in platinum-coated alumina boats along with $Tl_{1.7}Ba_2Ca_2Cu_3O_x$ (**Tl1.7**) pellets. The pellets were formed using a mechanical press at a pressure of 10000 kg., from a stoichiometric mixture of Tl_2O_3, BaO, CuO, and CaO.

The precursor films of the first sample group were deposited using a $Ba_2Ca_2Cu_3O_x$ target. The films were then annealed at 815°C for 10 hours in an air ambient using the T11.7 pellets without any physical contact between the films and pellets as shown in Fig. 1. The second sample group was obtained by annealing precursor films, deposited using a $Ba_2Ca_{2.3}Cu_3O_x$ target, for 20 hours in air ambient at 810°C and then reducing the temperature at 500°C at a rate of 1°C/min. The thallination pellet and the physical arrangement of the pellet and the samples, were the same as for the first sample group.

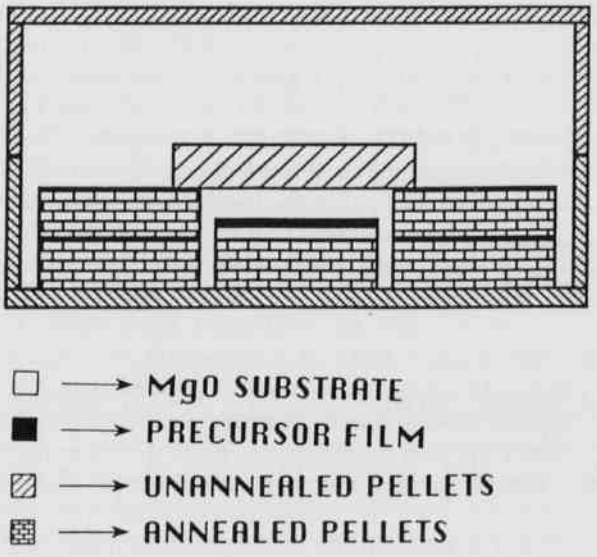

Fig. 1. Thallination configuration

Transition temperatures for the samples were obtained from plots of resistance (R) versus temperature (T) performed using a standard four-point contact method. Epotek H20E silver paste was used to attach four leads to the sample film (Ginley et al., 1988; Subramanium et al., 1990). The four leads were soldered to a module that fits into a cryogenic cooler capable of lowering the temperature at 19K. The thermostat, lock-in amplifier, and cryostat were all under the control of a personal computer.

J_c measurements were also performed using a simple four point contact arrangement (Lin et al., 1991). The sample was enclosed in a glass capsule and submerged in a tank of liquid nitrogen. The current through the sample was increased until the voltage across the sample became non-zero. T_c and J_c measurements were also performed using a inductive method. Inductively-Coupled Plasma (ICP) spectroscopy was used to study the composition of the sputtering targets as a function of sputtering time by scraping off the altered layer of the target material.

Reactive ion etching was used to define 120 μm lines and 200 μm concentric ring structures in $Ba_2Ca_2Cu_3O_x$ films deposited on <100>-oriented silicon substrates. Hunt's HPR-204 positive photoresist was used for masking. Conventional microelectronic fabrication techniques were used to deposit, define, develop and remove the photoresist. The reactive ion etching was performed using amixture of CI_2 (25%) and Ar for 45 minutes at a power density of 1 W/cm². Following the etching step, the photoresist was removed and a Dektak surface profilometer was used to examine the etch profiles.

Results and Discussion

The best precursor films obtained using the $Ba_2Ca_2Cu_3O_x$ and $Ba_2Ca_{2.3}Cu_3O_x$ targets were sputter-deposited using RF power densities of 1.1. W/cm² and 1.65 W/cm², respectively. The surface roughness of the precursor films was typically 40 Å. However, it was observed that surface roughness increases as RF sputtering power increases.

Fig. 2, showing a T_c value of approximately 119 K, is a resistance versus temperature plot of a typical sample from group one. EDS analysis of films produced using the $Ba_2Ca_2Cu_3O_x$ precursor target indicates that the films are predominantly of the (2212) phase. For these samples, the T_c is quite high, but the J_c value is low. Room temperature resistance of the film was measured to be about 30 ohms. This can be explained in terms of oxygen non-stoichiometry in the superconducting thin film which results due to tallination of the film in air ambient. Martin et al. (1990) have shown that, in bulk thallium cuprates, T_c is essentially governed by the oxygen non-stoichiometry. Furthermore, the conductivity of cuprate superconductors is primarily due to the cuprate planes so that as oxygen non-stoichiometry increases, the conductivity falls proportionately. The J_c results for this sample group is only about 5×10^3 A/cm², suggesting that these films are oxygen deficient.

ICP spectroscopy analysis of the target after several depositions revealed that the composition had changed to $Ba_{0.5}Ca_2Cu_{1.4}O_y$ from an original composition of $Ba_2Ca_2Cu_3O_x$. This indicates that calcium, unlike barium and copper, was not being depleted from the target even after many sputtering runs. This means that elemental components of the target were being consumed non-stoichiometrically because of preferential and selective sputtering (Betz and Wehner, 1983). Hence, pure (2223) phase films could not be obtained using the $Ba_2Ca_2Cu_3O_x$ target. Consequently, the calcium content in the second target was increased in order to be able to sputter (2223) phase precursor films.

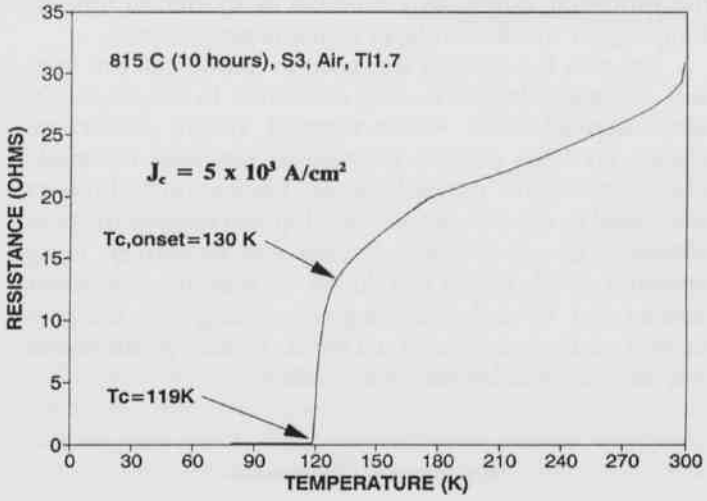

Fig. 2. T_c measurement plot of a typical sample from group one using four-point transport method.

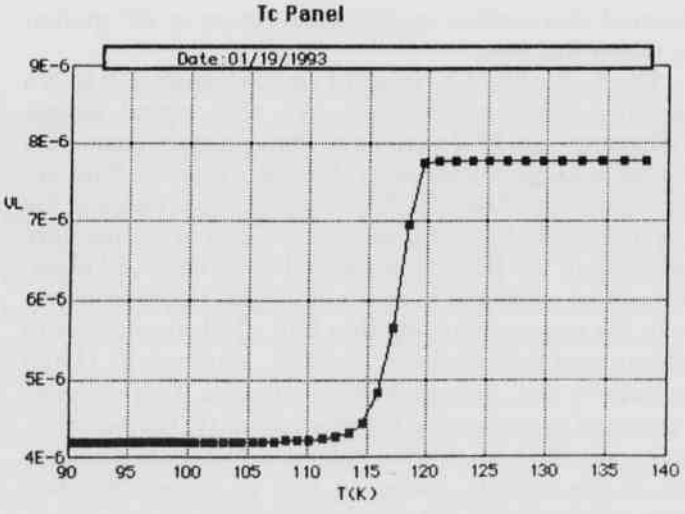

Fig. 3. T_c measurement plot of a typical sample from group two using inductive method.

Superconducting samples from group two typically yielded T_c values of 122 K and J_c values of 5 x 10^4 A/cm² as determined using the inductance measurement method (Fig. 3). The films were shiny black and extremely uniform with a density only slightly less than values previously reported for some of the best (2223) phase films. X-ray diffraction pattern for these films clearly show highly pure (2223) phase without any noticeable low T_c phase impurity spikes. The films are highly oriented with the C-axis normal to the substrate, consistent with the fact that longer anneling times are conductive to the creation of (2223) phase films.

Reactive ion etching of the precursor films using a Cl_2 and Ar plasma is anisotropic as evident from the sharp sidewalls of both the 120 μm lines and 200 μm concentric ring structures shown in Fig. 4. It is believed that activated chlorine species react with barium, calcium and copper in the precursor films to form their respected chloride species and that the etching is primarily accomplished by argon sputtering. The patterns etched in the precursor films can be tallinated to yield superconducting films.

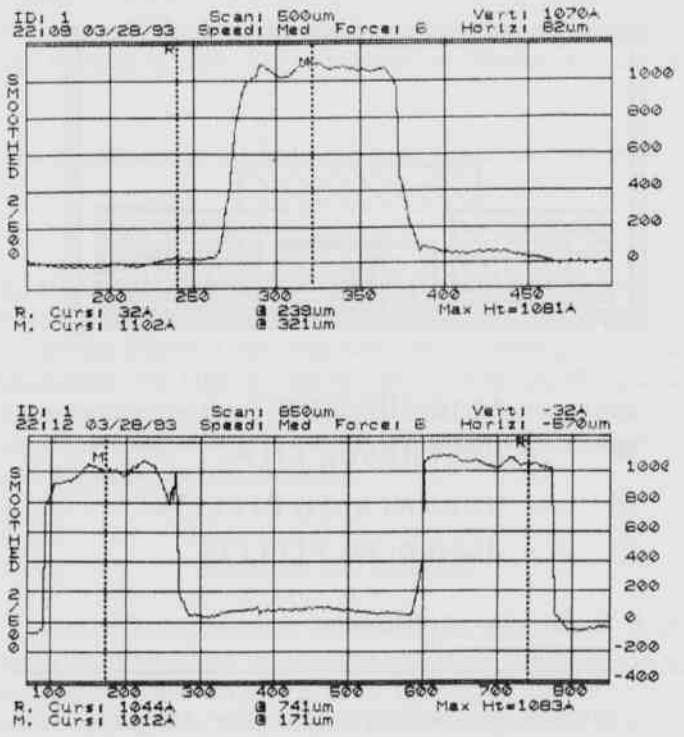

Fig. 4. Etch profiles for 120 μm line and 200 μm concentric ring structure.

Summary and Conclusions

A transition temperature of 119 K was achieved for (2212) phase films thallinated in an air ambient using a non-contact arrangement of the precursor film and thallium containing pellets. A low critical current density for this sample is attributable to oxygen deficiency. By enriching the sputtering target with calcium and optimizing the tallination conditions, pure (2223) phase superconducting films were readily fabricated. The (2223) phase films typi-

cally have a T_c of about 122 K and a J_c of about 5 x 10^4 A/cm^2. It was also shown that reactive ion etching using a mixture of CI_2 and Ar gases can be effectively used to pattern to precursor films.

Literature Cited

Betz G. and **Wehner G.K.,** 1983, Chapt. 2, Topics in Applied Physics, Springer-Verlag, Berlin Heidelberg.

deVries J.W.C., Dam B., Heijman M.G.J., Stollman G.M., Gijs M.A.M., Hagen C.W. and **Griessen R.P.** 1988. Appl. Phys. Lett., 52, 1904.

Ginley D.S., Kwak J.F., Hellmer R.P., Baughman R.J., Venturini E.L., Mitchell M.A. and **Morosin B.**1988. Physica C, 156, 592.

Lin J.G., Matsuishi K., Wang Y.Q., Xue Y.Y., Hor P.H. and **Chu C.W.** 1991. Physica C, 175, 627.

Martin C., Maignan A., Provost J., Michel C., Hervieu M., Tounier R. and **Raveau B.** 1990. Physica C, 168, 8.

Superconducting Technologies, Inc., Santa Barbara, California 93111, private communication.

Qui C.X., and **Shih I.** 1988. Appl. Phys. Lett., 53, 1122.

Shah S.I., Herron N., Fincher C.R. and **Holstein W.L.** 1990. Appl. Phys. Lett., 56, 782.

Sheng Z.Z., and **Hermann A.M.** 1988. Nature, 332, 138.

Sheng Z.Z., Kiehl W., Bennett J., El Ali A., Marsh D., Money G.D., Arammash F., Smith J., Viar D. and **Hermann A.M.** 1988. Appl. Phys. Lett., 52, 1738.

Sheng Z.Z., Sheng L., Su H.M. and **Hermann A.M.** 1988 Appl. Phys. Lett., 53, 2686.

Subramanium G., Radpour F. and **Kapoor V.J.** 1990. Appl. Phys. Lett., 56, 1799.

Distribution and Population Structure of Freshwater Mussels (Unionidae) in Lake Chicot, Arkansas

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Abstract

A systematic survey of mussel concentrations (= beds) in Lake Chicot was conducted during June 10-15, 1991. The lake was divided into 58 relatively equal-sized quadrats for qualitative survey by two, 2-man teams using Hookah dive systems. A qualitative survey revealed a single mussel bed encompassing an area approximately 12 km long and four m wide. For population analysis, the bed was sub-divided into five strata encompassing 9600 m^2 each. Twenty random, 4 x 1 m, quantitative samples were taken from each of the five strata. Four mussel taxa; *Amblema plicata* (threeridge), *Quadrula quadrula* (mapleleaf) *Quadrula nodulata* (wartyback), and *Plectomerus dombeyanus* (bankclimber), accounted for 99.6% of the specimens sampled. The total mussel population for the bed was estimated to be 59,304 ± 8,392. Potential for commercial harvest of Lake Chicot mussel resources is minimal at this time due to small shell size and poor shell quality.

Introduction

The distribution and taxonomy of Arkansas freshwater mussels has been reviewed by Gordon, et al. (1980) and Gordon (1981), and the biology, general distribution, and commercial utilization of Arkansas mussels has been discussed by Harris and Gordon (1991). Freshwater mussels often occur in dense concentrations, referred to as mussel beds or shell runs, with densities sometimes exceeding 100 individuals/square meter (m^2). To date, little effort has been made by the scientific, resource or regulatory communities to define the distribution and population size and structure of mussel beds within an entire lake or river system. This paper is the first of a series addressing the distribution and population structure of mussel beds in the larger rivers, impoundments, and lakes of Arkansas. These surveys will include the Black, Current, Ouachita, Saline, Spring, St. Francis, Strawberry, and White rivers, the Lake Ozark and Lake Dardanelle pools of the Arkansas River, Blue Mountain Lake, and, the subject of this paper, Lake Chicot.

Lake Chicot is located in Chicot County, extreme southeastern Arkansas, and is approximately 32 km north of the Arkansas - Louisiana line (Fig. 1). It is the largest natural lake in Arkansas (19.3 km^2), currently approximately 27 km long and approximately 0.8 km wide, and was created more than 600 years ago by meandering of the Mississippi River (Cooper, 1984; Nix and Schiebe, 1984; Cooper and Knight, 1987). The lake originally had excellent water quality and a small drainage area (200 km^2) with limited inflow from Connerly Bayou and outflow via Ditch Bayou (Cooper, 1984; Cooper and Knight, 1987). As a natural oxbow, Lake Chicot was subjected to periodic flushing by Mississippi River floodwaters before completion of the mainline Mississippi River levee (McHenry et al., 1984).

Channelization, basin enlargement by the 1927 flood, and construction of the Mississippi River levee enlarged the drainage area entering the lower lake via Connerly Bayou to 932 km^2 (Cooper, 1984). The increased inflow from the enlarged watershed formed a sand spit which partially isolated the northern part of the lake following the 1927 flood (Cooper, 1984). In 1948 additional materials were added to the sand spit to form a permanent levee which divided the lake into an isolated upper basin (3.9 km^2) and a larger flow-through lower basin (15.4 km^2) (Cooper and Knight, 1987). Sedimentation rates since 1954 have averaged 1 - 4 cm/yr, depending on location within the lake, and rates have been two to three times greater in the lower lake than in the upper lake (McHenry et al., 1984).

Lake Chicot morphology is typical of a large river bend with a deep thalweg along the outside bendway (Cooper, 1984). The inshore area consists of a sandy littoral zone which drops rapidly to the lake bottom (maximum depth approximately 9.5 m). The littoral zone on the inside bendway has a much more gentle slope, and the substrate is covered by fine silt and muck.

Cooper (1984) conducted a survey of Lake Chicot molluscans from 1977 through 1981 and identified 17 taxa from the system. Cooper concentrated his efforts in the shallower lake reaches and collected by hand grabbing, shallow diving, and raking or dip netting mussels. Deeper portions of Lake Chicot were sampled by Ekman and Peterson dredges.

Journal of the Arkansas Academy of Science, Vol. 47 [1993], Art. 9

Materials and Methods

Lake Chicot was subdivided into 58 relatively equal sized quadrats on 7.5 minute topographic maps to facilitate qualitative survey of the mussel fauna. Two, 2-man teams using Hookah dive rigs mounted in separate boats were utilized to search the qualitative quadrats. Qualitative survey methodology consisted of haphazardly exploring all habitat types within a quadrat, collecting vouchers of all mussel species encountered (both live and dead), and recording the location of mussel concentrations within each quadrat. The qualitative quadrat survey defined the size and location of one expansive mussel bed within the lake.

Once the bed was defined, quantitative sampling was initiated to estimate the population numbers for each species and the total mussel population. An attempt was made to stratify beds based on physical habitat variables such as water depth, substrate type, riparian land use (wooded, agricultural, residential) or location relative to geographic variables (e.g., tributary stream inflow, outflow, bendways). Since this bed was uniform in physical structure, it was somewhat arbitrarily divided into five equal sized strata for quantitative sampling (Fig. 1).

Twenty 4 x 1 m random samples were collected from each stratum for a total of 100 4 x 1 m quantitative samples. Sample locations were selected by utilizing a random numbers generator. A 1.0 m^2, weighted quadrat constructed of 2.0 cm diameter PVC pipe was used to define the sample area. The quadrat was placed at the most inshore point within the mussel bed at each sample site and flipped end over end toward mid-lake (generally downslope) until a 4 x 1 m area was sampled.

All mussels encountered by hand searching the quadrat area were bagged and brought to the surface for indentification and enumeration. Underwater visibility was zero at depths greater than 1.0 m. Nomenclature follows Turgeon et al. (1988). Each mussel was measured for either length or depth to the nearest 0.1 mm using dial calipers. Length was measured at the longest point from the anterior to posterior of the mussel. Depth was measured from the umbones to the ventral shell edge. The axis measured was determined by the definition of legal commercial size for a particular species. All specimens were weighed to the nearest 0.1 g with a portable electronic balance.

Voucher specimens were collected for each species and deposited in the Freshwater Mussel Collection of the Arkansas State University Museum of Zoology. Soft parts were preserved by first narcotizing live mussels in a MS 222 solution, then fixing the tissues in 10% formalin solution. Specimens were later soaked in water and transferred to 40% isopropanol for storage.

Summary statistics including mean, minimum, maximum, standard deviation, variance and sum were calculated for each stratum and for the entire data set. All summary statistics were performed using SYSTAT (Wilkinson, 1990).

Quantitative estimates were made using the Sampford method (Huebner et al., 1990) where the total number of mussels (by species or population) is:

$$[1]\quad x = \Sigma y_i \cdot g_i$$

where x is the total number of mussels in the lake, i is the number of strata, y_i is the sample total (total number of organisms encountered in all the n_i sampling units) and g_i is the raising factor ($g_i=1/f_i$, where f_i if the fraction sampled, and is defined by n_i/N_i with n_i being the number of sampling units counted in the ith stratum, and N_i the total potential number of sampling units in the ith stratum).

The 95% confidence interval (CI) around the total number of mussels in the lake is given by:

$$[2]\quad x \pm (t \cdot \sqrt{\Sigma N_i^{\,2} \cdot S^2 y_i \cdot (1\text{-}fi / ni)})$$

where S^2y_i is the sample variance computed from raw counts in the n_i sampling units in the ith stratum, and t is the Student's t for the effective degrees of freedom.

The effective degrees of freedom are given by:

$$[3]\quad 1/\Sigma\,(L_i^{2}) / \mathrm{df}$$

where

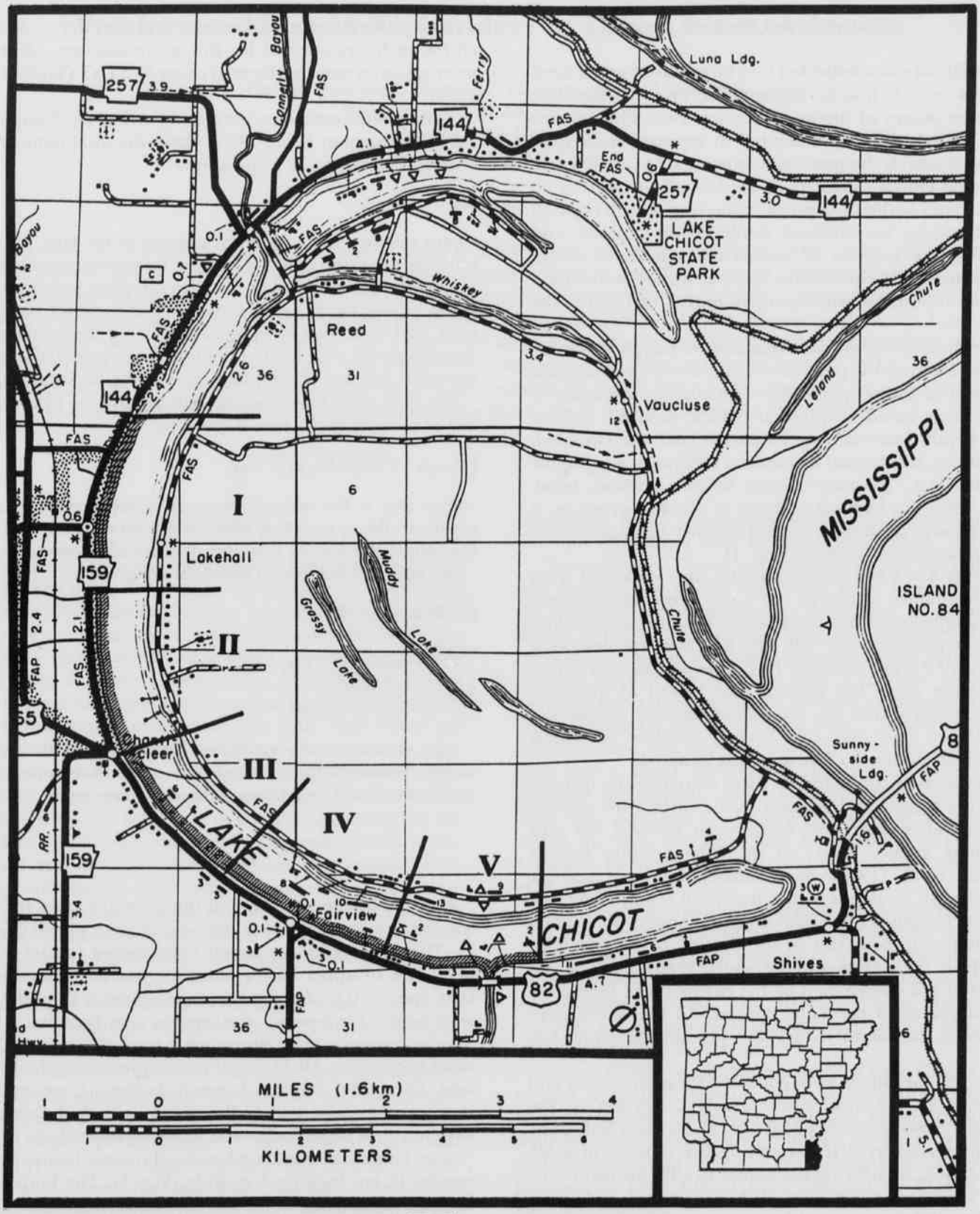
$$Li = \frac{N_i^2 \cdot S^2_{yi} \cdot (1\text{-}fi) / ni}{\Sigma N_i^2 \cdot S^2_{yi} \cdot (1\text{-}fi) / n_i}$$

Age versus growth estimates, length or depth versus weight relationships and age/size class distribution for each species will be addressed in a separate paper.

Results

A qualitative survey revealed the presence of 14 species within the upper and lower portions of Lake Chicot (Table 1). The upper lake supported very limited mussel numbers. The 14 upper lake qualitative quadrats yielded only four species (*Quadrula quadrula*, mapleleaf; *Q. nodulata*, wartyback; *Plectomerus dombeyanus*, bankclimber; and *Anodonta grandis*, giant floater) in a total of 30 live and 10 dead specimens. All 14 species were present in the lower lake. Three of these taxa, *Lampsilis hydiana* (Louisiana fatmucket), *Lampsilis teres* (yellow sandshell), and *Potamilus ohiensis* (pink papershell) were found as relict shells only.

The lower lake contained a singel mussel bed approximately 12 km long by 4 m wide (Fig. 1). The horizontal and vertical location of the mussel bed is illustrated in Fig. 2. Generally, the bed was located 25 - 35 m from the



I-V = Strata; ▨ = Limits of mussel bed.

Fig. 1. Location of Lake Chicot, mussel bed, and strate for quantitative sampling.

shoreline, and its location was closely associated with the "breakover point" separating the relatively shallow littoral areas and the precipitous slope descending to the lake bottom. The bed was usually found at depths ranging from 4 - 6 m, and substrate consisted of a firmly packed, fine to medium grain sand.

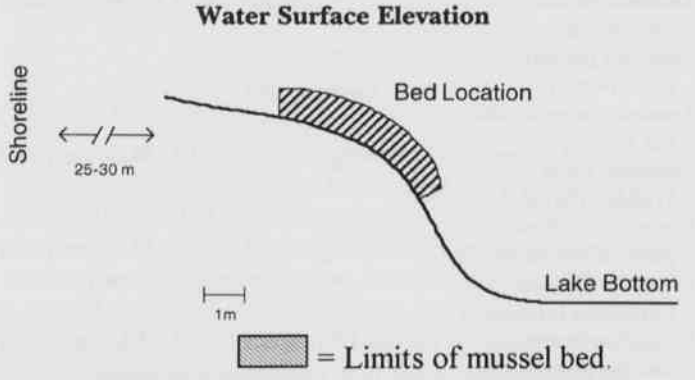


Fig. 2. Profile illustrating horizontal and vertical location of Lake Chicot mussel bed.

Table 1. Mussels collected from qualitative search quadrats.

Species Common Name	Live	Dead
Amblema plicata threeridge	221	45
Anodonta grandis giant floater	0	27
Anodonta suborbiculata flat floater	1	1
Lampsilis hydiana Louisiana fatmucket	0	1
Lampsilis teres yellow sandshell	0	10
Leptodea fragilis fragile papershell	1	13
Megalonaias nervosa washboard	1	0
Obliquaria reflexa threehorn wartyback	0	1
Plectomerus dombeyanus bankclimber	67	13
Potamilus ohiensis pink papershell	0	1
Potamilus purpuratus bleufer	3	16
Quadrula nodulata wartyback	76	20
Quadrula pustulosa pimpleback	2	0
Quadrula quadrula mapleleaf	195	48
Total - 14 Species	567	196

Within the lower lake mussel bed, densities ranged from 0 - 16 mussels / 4 x 1 m quantitative quadrat. Mean mussel densities across strata were relatively uniform with values of 5.1, 4.2, 6.3, 3.9, and 5.3 for strata I through V respectively. Mean mussel density for all quantitative samples was 4.9 / 4 x 1 m unit, standard deviation = 3.6.

Table 2 shows that bed population structure was dominated by four taxa, *Amblema plicata, Quadrula quadrula, Quadrula nodulata,* and *Plectomerus dombeyanus*, which comprised 99.6% of the total bed population. The population estimate was greatest for the threeridge, which composed 46% of the total mussel community (Table 2). Population estimates were calculated separately using individual variances, so Table 2 species estimates do not sum to the Total. Areas outside the defined bed contained very low mussel densities.

Legally harvestable mussels were virtually restricted to the threeridge and bankclimber populations. Approximately 88% of threeridges were of legal harvest size, and 72% of bankclimbers were legal size.

Table 2. Number collected, percent of total, percent legally harvestable, and population estimates derived from quantitative samples of the Lake Chicot mussel bed.

Species Common Name	Number Collected	Percent of Total (% legal)	Population Estimate
Amblema plicata threeridge	222	45.7 (87.8)	26651 ± 6000
Quadrula quadrula mapleleaf	126	25.9 (2.0)	15126 ± 2980
Quadrula nodulata wartyback	91	16.7 (1.2)	10924 ± 2585
Plectomerus dombeyanus bankclimber	55	11.3 (72.0)	6604 ± 1730
Anodonta grandis giant floater	1	0.2 (NCV)	124 ± 250
Obliquaria reflexa threehorn wartyback	1	0.2 (0)	121 ± 250
Total	496	100.0	59304 ± 8392

Discussion

Cooper (1984) reported 14 unionid mussel species and

the Asiatic clam, *Corbicula fluminea* from Lake Chicot (Table 3). Six species listed by Cooper were not found during the present survey. These include *Fusconaia flava* (Wabash pigtoe), *Lampsilis ovata* (= *Lampsilis cardium*, plain pocketbook), *Lampsilis straminea claibornensis* (southern fatmucket), *Quadrula apiculata* (southern mapleleaf), *Quadrula rumphiana* (ridged mapleleaf), and *Villosa lienosa* (little spectaclecase). Part of the discrepancy between species reported by Cooper (1984) and our survey is based in taxonomic uncertainty. Although *Quadrula apiculata* has been found as far north as the lower Ohio and Tennessee rivers, all voucher specimens from Lake Chicot were determined to be *Quadrula quadrula* (D. Stansbery pers, comm.). The distribution of *Quadrula rumphiana* is considered restricted to the Mobile River system (D. Stansbery, pers. comm.). Therefore, the senior author has chosen to refer to all "mapleleaf" specimens collected during this survey as *Quadrula quadrula*.

The present study found five species not reported by Cooper (1984). These include *Anodonta suborbiculata* (flat floater), *Leptodea fragilis* (fragile papershell), *Megalonaias nervosa* (washboard), *Obliquaria reflexa* (threehorn wartyback, and *Quadrula nodulata* (wartyback). The first four species, flat floater, fragile papershell, washboard, and threehorn wartyback were rare and represented by few individuals in our collections. The wartyback, however, was relatively common, and its omission from the Cooper study is curious. Its presence in our survey and absence in Cooper's may be the result of different collection methodologies. The wartyback is typically found in deeper water and our survey emphasized deepwater habitats whereas the Cooper survey emphasized inshore searches. As a final taxonomic note, *Leptodea laevissima* reported by Cooper (1984) has been synonomized with *Potamilus ohiensis* (Turgeon et al., 1988; A. Bogan, pers. comm.).

Substrate appeared to be the primary limiting factor of mussel numbers in upper Lake Chicot. Substrates toward mid-lake and in sheltered, wooded sections were composed of very fine silt and muck ranging from 0.5 - >1.0 m in depth. Inshore areas subject to wave action were virtually devoid of fine substrates, but instead, were composed of very dense, hard packed clay which may be unsuitable for mussel colonization.

The number and size of specimens sampled indicate that the bankclimber and threeridge provide the only real potential for commercial mussel harvest from Lake Chicot. However, bankclimbers are rarely saleable, and the commercial quality of Lake Chicot threeridges was poor because of nacre staining. Only two percent of the mapleleaf population and one percent of the wartyback population were legally harvestable. Overall, the Lake Chicot mussel population has little commercial value.

Table 3. Comparison of mussel species collected by Cooper (1984) and the present study.

Species Common Name	Cooper (1984)	This Study
Amblema plicata threeridge	*	*
Anodonta grandis giant floater	*	*
Anodonta suborbiculata flat floater		*
Fusconaia flava Wabash pigtoe	*	
Lampsilis cardium plain pocketbook	*	
Lampsilis hydiana Louisiana fatmucket	*	*
Lampsilis straminea southern fatmucket	*	
Lampsilis teres yellow sandshell	*	*
Leptodea fragilis fragile papershell		*
Megalonaias nervosa washboard		*
Obliquaria reflexa threehorn wartyback		*
Plectomerus dombeyanus bankclimber	*	*
Potamilus ohiensis pink papershell	*	*
Potamilus purpuratus bleufer	*	*
Quadrula apiculata rough mapleleaf	*	
Quadrula nodulata wartyback		*
Quadrula pustulosa pimpleback	*	*
Quadrula quadrula mapleleaf		*
Quadrula rumphiana ridged mapleleaf	*	
Villosa lienosa little spectaclecase	*	
Total - 20 Species	14	14

Acknowledgements

Funding for this project was provided by the Arkansas Game and Fish Commission, the U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers. The

uthors appreciate the assistance of A. Carter, S. Filipek, R. Roberg, and L. Rider, of the AGFC; P. Hartfield and J. Stewart of the USFWS; and L. Cockman and D. Heffington of the USACOE. R. Doster and P. Bryant assisted with manuscript preparation. J. Nichols assisted with all phases of planning and implementation of this research, and his hard work in the field was essential to completion of this project.

Literature Cited

Cooper, C.M. 1984. The freshwater bivalves of Lake Chicot, an oxbow of the Mississippi in Arkansas. The Nautilus 98(4):142-145.

Cooper, C.M. and **S.S. Knight.** 1987. Residual pesticides in fishes from Lake Chicot, Arkansas. Proc. Ark. Acad. Sci. 41:26-28.

Gordon, M.E. 1981. Recent Mollusca of Arkansas with annotaions to systematics and zoogeography. Proc. Ark. Acad. Sci. 34:58-62.

Gordon, M.E., L.R. Kraemer and **A.V. Brown.** 1980. Unionacea of Arkansas: historical review, checklist, and observations on distributional patterns. Bull. Amer. Malacol. Union 1979:31-37.

Harris, J.L. and **M.E. Gordon.** 1991. Arkansas mussels. Arkansas Game and Fish Commission, Little Rock. 32 pp.

Huebner, J.D., D.F. Malley and **K. Donkersloot.** 1990. Population ecology of the freshwater mussel *Anodonta grandis grandis* in a Precambrian shield lake. Can. J. Zool. 68:1931-1941.

McHenry, J.R., F.R. Schiebe, J.C. Ritchie and **C.M. Cooper.** 1984. Deposited sediments of Lake Chicot. Pp. 18-47, *In* Limnological study of Lake Chicot, Arkansas. (J.F. Nix and F.R. Schiebe, eds.) Proc. Arkansas Lakes Symp., Ouachita Baptist Univ., Arkadelphia, AR.

Nix, J.F. and **F.R. Schiebe.** 1984. Limnological study of Lake Chicot, Arkansas. Proc. Arkansas Lakes Symp., Ouachita Baptist Univ., Arkadelphia, AR. 146 pp.

Turgeon, D.D., A.E. Bogan, E.V. Coan, W.K. Emerson, W.G. Lyons, W.L. Pratt, C.F.E. Roper, A. Scheltema, F.G. Thompsom and **J.D. Williams.** 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks. Am. Fish. Soc. Special Publ. 16. Am. Fish. Soc., Bethesda, MD. 277 pp.

Wilkinson, L. 1990. SYSTAT: The system for statistics. SYSTAT, Inc., Evanston, IL.

Fishes of Bayou Meto and Wattensaw Bayou, Two Lowland Streams in East Central Arkansas

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Abstract

Bayou Meto is a low-gradient, highly turbid, warm-water stream that originates in the foothills of the Interior Highlands of central Arkansas and flows southeastward 290 km to the Arkansas River. In the 1970's, Bayou Meto was contaminated with dioxins from a point source (Vertac Corp.) now recognized as a USEPA Superfund site. The present study was initiated to investigate the impact of dioxin on the fish community of Bayou Meto. Fishes were collected by backpack-electrofishing, boat-electrofishing, seines, hoopnets, minnow traps, and trot lines, at 14 sampling stations. Diversity indices (Shannon and Margalef) were used to compare diversity among sample sites. A total of 73 fish species was collected from Bayou Meto and Wattensaw Bayou (a reference stream) between May, 1991 and September, 1992. A total of 79 species had been reported from these drainages. I collected 64 species from Bayou Meto and 48 species from Wattensaw Bayou. Of the 79 species historically reported from these drainages, 17 were not collected during this study. However, of the 73 species collected, 11 (15% of the entire collection) had not been previously recorded from these drainages. There was 57% overlap in species between Bayou Meto and Wattensaw Bayou. Differences in collected species from the two drainages mostly involved rare species i.e., those species in low abundance according to the literature and/or difficult to collect. Centrarchids and castostomids dominated the fish communities of both streams. Percids were also well represented, but 50% were not previously reported from these drainages. Cyprinidae numbers were low and distributions spotty. Diversity varied among sites and was related to impacts and stream order. Diversity was highest at less impacted locations and downstream sites.

Introduction

Surveys of species are the cornerstone of ecological studies, providing basic data about what is present or absent in an ecosystem. Listing and recording the occurrence of species is indispensable to science, from the discovery of new species to affirmation of the anticipated. Species lists from geographical regions or from specific systems provide baseline data for future studies. Species and population baselines have become increasingly important to understanding the impacts of massive habitat alterations, pollution, introduction of non-native species, and recovery of endangered species.

The overall objective of this study was to describe the fish communities of Bayou Meto and Wattensaw Bayou for present and future reference. This study was part of a larger study funded by the U. S. Enviromental Protection Agency and the U. S. Fish and Wildlife Service for the Arkansas Cooperative Fish and Wildlife Research Unit to investigate the impact of dioxins upon the aquatic community of Bayou Meto.

Bayou Meto is a low-gradient, highly turbid, warm-water stream that originates in the foothills of the Interior Highlands of central Arkansas (Fig. 1). Bayou Meto begins 38.8 km northeast of Jacksonville, Arkansas, and flow southeastward 290 km through the flat, fertile farmlands of the Mississippi Embayment to the Arkansas River near Reydell, Arkansas. The entire drainage area for Bayou Meto is 1,606 km^2 (Neely, 1985). Based upon 30 years of monitoring at the United States Geological Survey (USGS) gauging station at Lonoke, Arkansas, the average flow for Bayou Meto at Lonke is 8.2 m^3/s; minimum and maximum flows were 0 and 133 m^3/s, respectively (Neely, 1985).

Bayou Meto begins as an intermittent stream at an elevation of 500 m and becomes a second order stream 12.9 km above Jacksonville. The headwaters are characteristic of an upland stream with typical riffle and pool complexes. Bayou Meto becomes a third order stream 9.2 km above Jacksonville at its confluence with Bridge Creek, a fourth order stream at Bayou Meto Wildlife Refuge, and enters the Arkansas River as a fifth order stream.

A paucity of acquatic faunal studies in east-central Arkansas and the impacts of dioxins, sewage, and pesticides from industry, municipalities, and agriculture necessitated comparison of the fish fauna of Bayou Meto to a

less impacted stream to ascertain patterns of species alterations. Since 1970, dioxin-laden waste chemicals have been discharged from Vertac Chemical Corp. into Bayou Meto (ADPC&E, 1984, 1989). The Vertac site has been declared a Superfund Site by USEPA (USEPA, 1990, 1991).

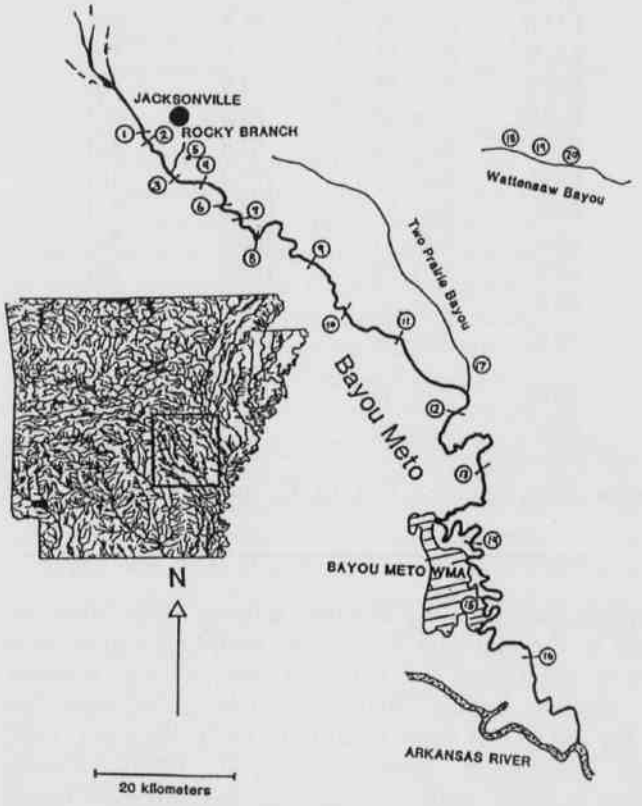


Fig. 1. Sample stations on bayous Meto and Wattensaw. Number in circle indicates location and station. Station 5 was Lake Dupreee. Bayou Meto Wildlife Management area (WMA) is denoted by paraellel lines.

Wattensaw Bayou was used as a reference stream to Bayou Meto. Wattensaw Bayou begins 3 km southeast of Cabot, Arkansas, within 16 km of Bayou Meto, and flows eastward for 103.5 km before its confluence with the White River. These two streams are morphologically similar, flowing through the Mississippi Alluvial Plain of Arkansas. Both are meandering streams with large variances in seasonal flows. Deposition in both systems includes clay, sand, gravel, and detritus. The riparian zones of both streams are dominated by bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa acquatica*). The fish communities of these lowland streams should be dominated by Centrarchidae (Lee et al., 1980; Robinson and Buchanan, 1988), a family of fishes particularly adapted to the slow moving and turbid waters found in bayous of east central Arkansas. The native fish species compositions of both Meto and Wattensaw bayous were hypothesized to be similar. However, there is no known point source of effluent flowing into Wattensaw Bayou. Except for agricultural practices that dominate the lower reaches of both rivers, Wattensaw Bayou is not known to be highly polluted and, therefore, useful as a control to Bayou Meto.

Physicochemical parameters were analyzed in an seperate study and these parameters followed patterns in downstream gradients as predicted by Vannote et al. (1980) and others (Heckathorn, 1993). Assumptions made of these two drainages were that all sampling stations should produce relatively similar species, richness, and diversity with trends toward increasing numbers downstream and differences among sampling stations within Bayou Meto and between bayous Meto and Wattensaw should correlate to point source inputs. The above assumptions are based upon Heckathorn (1993) and personal observations.

Materials and Methods

In May, 1991, 12 sampling stations were designated on Bayou Meto and two sampling stations on Wattensaw Bayou (Fig. 1; Table 1). Fish collection methods included backpack-electrofishing, boat-electrofishing using a 240 V, 3500 W DC electrofishing boat adjusted to five amperes, seining, hoop nets, minnow traps, and trot lines (Nielson and Johnson, 1985). Collection sites were sampled during daylight hours intermittently from May through October, 1991. Seining proved impractical at most stations because of extensive vegetation, including both dead and living trees. At the end of the 1991 field season, sampling sties were confirmed (Table 1) and a sampling regime was designed and developed for 1992. Intensive sampling occurred in May and September of 1992 at all stations. Each sampling station was measured at 75-100 m of stream length (Owens and Karr, 1978; Schlosser, 1982). The sampling regime consisted of three 20-min. boat-electrofishing runs, accompanied by one set of two 24-h 576 mm diameter hoopnet (1 baited and 1 unbaited) and one set of eight 24-h unbaited minnow trap. Both banks of each station were boat-electrofished using a 240 V, 3500 W DC electrofishing boat adjusted to five amperes, with the same pattern of 100 m downstream and then 100 m upstream of the opposite bank being followed on all three runs. All electrofishing was done during daylight hours. Immediately after electrofishing hoopnets and minnow traps were set. Hoopnets were placed with the unbaited

Journal of the Arkansas Academy of Science, Vol. 47 [1993], Art. 1

Table 1. Sampling stations with locations, counties, legal descriptions, distance from the river source, and stream order. BM is bayou Meto, WB is Wattensaw Bayou, and WMA is Wattensaw Wildlife Management Area. The first of two Sewage Treatment Plants discharges into Bayou Meto above Station 3, and the second plant discharges above Station 4. Rocky Branch confluence with Bayou Meto is between stations 3 and 4.

Stations	River Locations	Counties	Legal Descriptions			Km	Stream Order
BM-1	Macon Br.	Pulaski	3N,	R11W,	Sect. 5	26.9	2nd
BM-2	Cato Br.	Pulaski	T3N,	R11W,	Sect. 22	35.3	3rd
BM-4	Reeds Br.	Pulaski	T3N,	R11W,	Sect. 31	41.9	3rd
BM-6	Broken Br.	Pulaski	T3N,	R10W,	Sect. 33	44.9	3rd
BM-7	I-40 Br.	Pulaski	T2N,	R10W,	Sect. 14	55.8	3rd
BM-8	HWY 15 Br.	Lonoke	T2N,	R9W,	Sect. 29	61.4	3rd
BM-11	HWY 13 Br.	Lonoke	T1N,	R8W,	Sect. 10	107.4	3rd
BM-12	HWY 165 Br.	Lonoke	T2S,	R6W,	Sect. 7	133.6	3rd
BM-13	HWY 79 Br.	Arkansas	T3S,	R6W,	Sect. 11	166.3	3rd
BM-14	HWY 152 Br.	Arkansas	T3S,	R6W,	Sect. 33	182.0	4th
BM-15	Cox Cypress	Arkansas	T5S,	R6W,	Sect. 1	218.7	4th
BM-16	HWY 11 Br.	Arkansas	T6S,	R5W,	Sect. 3	253.9	4th
WB-18	HWY 13 Br.	Prairie	T3N,	R9W,	Sect. 12	60.5	2nd
WB-20	WMA	Prairie	T3N,	R6W,	Sect. 22	90.7	4th

NOTE: Only Cox Cypress (BM-15) was deleted from the 1992 sampling regime. Also, stations 3, 5, 9, 10, 17, and 19 were used in the sediment and invertebrate part of the overall dioxin contamination study.

net immediatly downstream of each 100 m sampling station and with the baited net immediately upstream. Minnow traps were placed randomly throughout the sampling station. Block nets were not used due to possible high levels of dioxin contamination. The sampling was repeated again in September, 1992, but hoopnets and minnow traps were not set due to poor catches during spring sampling. Fish species lists for both Bayou Meto and Wattensaw Bayou were compiled from data collected from the 1991 random sampling and the 1992 sampling regime.

Most collected fishes were fixed in 10% formalin, washed in water, preserved in 50% isopropyl alcohol, and returned to the lab for identification. Large fish were identified in the field and returned unharmed. Specimens were eventually changed to 70% ethanol and placed into the University of Arkansas Natural History Museum in Fayetteville, Arkansas. The Common and Scientific Names of Fishes published by the American Fishery Society was used to name fish species collected (Robins et al., 1991). Species identifications were confirmed in the lab by Dr. James E. Johnson, U.S. Fish and Wildlife Service.

Electrofishing, hoopnets, and minnow traps catch per unit effort (CPUE) in the 1992 sampling regime was consistent among sites and allowed for comparisons among sampling stations using diversity indices. Only fishes collected in the May and September sampling regime were used to determine and compare diversity and richness. Two diversity indices (Shannon and Margalef) were chosen for use in this study (Shannon, 1958; Margalef, 1958, 1963; Washington, 1984; Boyle et al., 1990). Diversity indices elucidate differences among sites and show trends in declines or increases in diversity. Boyle et al. (1990), showed that best results are obtained by using indices in concert, thus allowing for complementation and dampening of deficiencies.

Shannon and Margalef indices were chosen based upon wide use, acceptance in aquatic studies, and distinction in responses to variances in populations (Washington, 1984; Boyle et al., 1990).

Results

Sampling efficiency was subjectively assesed as excellent to good for the 1992 electrofishing effort. The first and second of the set of three electrofishing runs collected 81% and 91% of the species, respectively, and numbers of fish collected declined with each successive run. These data are judged adequate to make inferences about

species presence or absence, richness (total number of species), and diversity.

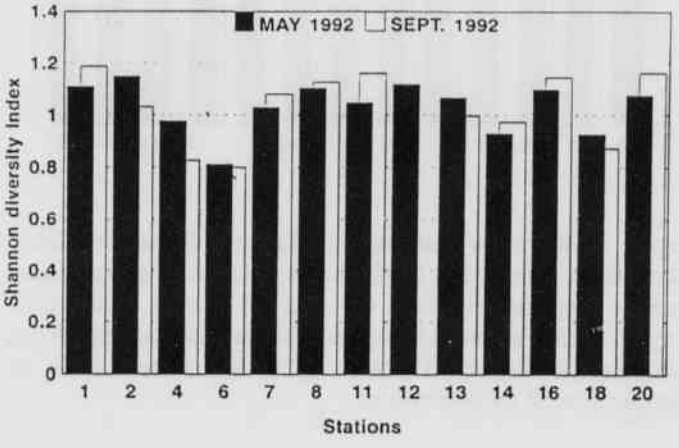
A total of 73 fish species was collected from bayous Meto and Wattensaw between May, 1991, and September, 1992 (Table 2). Seventy-nine species had been reported from the regional area of these drainages (Lee et al., 1980; Robison and Buchanan, 1988). Sixty-four fish species were collected from Bayou Meto and 48 species from Wattensaw Bayou. Fishes collected in only one of these two drainages are shown in Table 3. Of the 79 species historically reported from these drainages, 17 (22%) were not found during this survey. Conversely, of the 73 species collected, 11 (15%) had not been previously recorded from these drainages. There was a 53% overlap in species between Bayou Meto and Wattensaw Bayou.

Centrarchids and catostomids dominated the fish communities of both streams. *Polyodon spathula* and *Anguilla rostrata* were both collected only from Wattensaw Bayou, and only in low numbers. Gars were represented in both streams at all stations by *Lepisosteus oculatus*, but *L. platostomas* was collected only in Bayou Meto and *L. osseus* only in Wattensaw Bayou. *Amia calva* was well represented in both systems. Cyprinids were represented by shiners and minnows, but their species numbers were notably low and their distributions spotty and variable. Shiners in Wattensaw had a higher diversity than in Bayou Meto. Ictalurids were represented in both streams; *Ictalurus punchtatus* was most abundant. Esocids were represented in both systems by *Esox americanus. Aphredoderus sayanus* was abundant in Bayou Meto but absent from Wattensaw Bayou. The family Cyprinodontidae was well depicted by *Fundulus olivaceus* in both drainages, but *F. notatus* was taken only from Bayou Meto, and then only in low numbers. *Gambusia affinis*, and at least one of two species of Atherinidae, were collected at most stations in both streams. The family Percicthyidae was represented by *Morone mississippiensis* in low numbers in both bayous, and *M. saxatilis* was collected once at mid-stream in Bayou Meto. Percids were well represented, considering their lack of susceptibility to electrofishing (Vibert, 1967, Novotny and Priegel, 1974). Percidae also had the highest percentage of unreported species, with 50% as newly described from these drainages in this work. *Aplodinotus grunniens* was collected at all sampling stations except Station 4 on Bayou Meto. Some of the highest dioxin contamination concentrations in Bayou Meto were reported from Station 4 (ITC, 1987, USEPA, 1990, 1991).

Species diversity varied by station (Fig. 2). However, relative diversity trends did not vary greatly between indices nor between May and September sampling dates, and congruence between these parameters ameliorates validation of sample methodologies and these data. The highest diversities from Bayou Meto were consistently found at stations 1, 2, and 12, with the lowest diversities at stations 4 and 6, where dioxin levels and sewage effluent were highest (ITC, 1987, USEPA, 1990, 1991) (Fig. 2). Sewage effluent negatively impacts fish communities immediately downstream, but further downstream beyond the septic and/or toxic zone, benefits may be derived by certain fish species due to increases in flow and nutrients (Owens and Karr, 1978). Diversity in Bayou Meto remained unpredictable low from stations 4 through 12. At stations 14 and 16, increases in width, depth, and turbidity of the stream may have reduced sampling efficiency, resulting in an underestimate of diversity and richness (Schlosser 1982; Heckathorn, 1993). Diversity in Wattensaw Bayou was relatively low at the upper station and highest at the most downstream station. Station 20 at Wattensaw had the highest diversity and richness of any station (Figs. 2 and 3).

Richness proved variable among sampling dates. Total numbers of species in May fluctuated less and averaged higher than in September. Numbers of species for both sampling dates followed the same trend as seen in the diversity indices, except that May results were not as conspicuously low. Contrasts between samples taken in May and September, were most likely due to differences in flow. For example, in September, water flows dropped to levels which prevented the sampling of Station 12. Fishes might have emmigrated out of my sampling stations to deeper waters. Lower water levels should also concentrate fishes, making them more susceptable to collecting gear. In general diversity and richness decreased at stations with decreases in water levels, but realative diversity and richness remained consistent among stations in between May and September sampling dates.

Diversity indices for Bayou Meto and Wattensaw Bayou



Diversity indices for Bayou Meto and Wattensaw Bayou

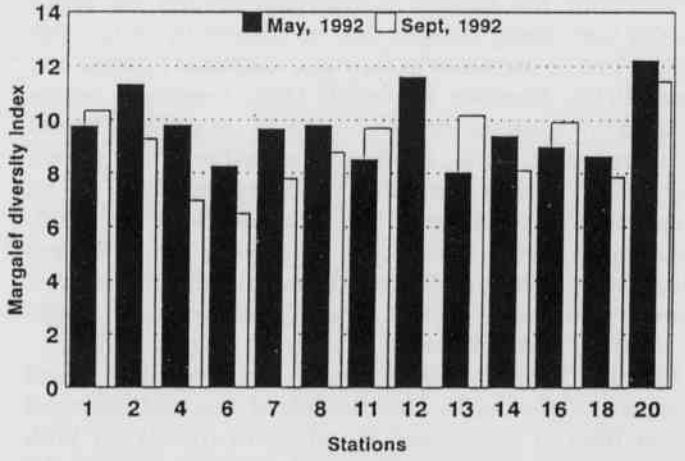


Fig. 2. Diversity by stations for May and September sampling dates. Stations 1 and 2 are upstream of dioxin and sewage impacts. Stations 18 and 20 are at unimpacted Wattensaw Bayou. We were unable to sample station 12 in September due to low flow.

Richness of Bayou Meto and Wattensaw Bayou

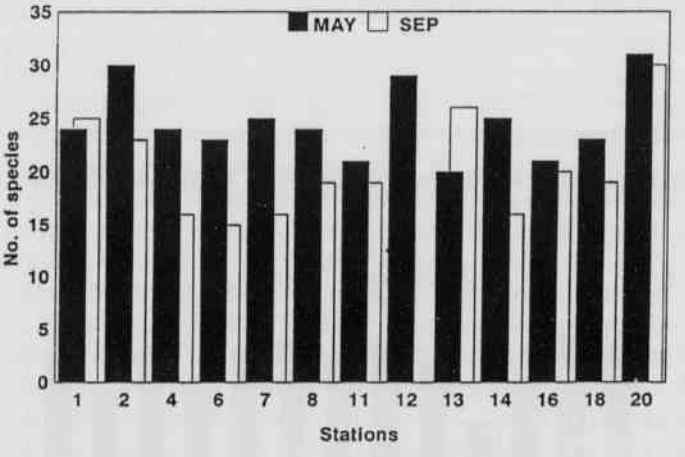


Fig. 3. Richness by stations for May and September sampling dates. Stations 1 and 2 are upstream of dioxins and sewage impacts. Stations 18 and 20 are at Wattensaw Bayou. Richness should increase downstream as seen from unimpacted stations 1-2 and 18-20. We were unable to sample site 12 in September.

Discussion

Differences in species collected from the two drainages mostly involved rare species (those collected in low numbers or at only one station). It is likely that these species were present in low numbers in both streams. However, 15 species were collected in substantial numbers in one drainage but not the other: *Lepisosteus platostomas, Cyprinus carpio, Lythrurus umbratilis, Carpoides carpio, Ictiobus niger, Ictalurus furcatus, Aphredoderus sayanus, Fundulus notatus, Centrarchus macropterus, Micropterus punctulatus, Etheostoma chlorosomum, E. spectabile,* and *Percina maculata* came only from Bayou Meto, and *Lepisosteus osseus* and *Notropis texanus* came only from Wattensaw Bayou (Table 3).

Many of the 17 species reported from bayou Meto and Wattensaw, but not collected during this study, are not susceptible to electrofishing, and other species, if present, would be expected in low numbers, reducing their chances of capture (Table 3). For example, *Polyodon spathula* was collected from Wattensaw Bayou, but only by chance. During a water quality sampling effort, not during fish collection efforts I chanced upon a fisherman, whom was catching young *P. spathula* on minnows. Fish like *P. spathula, Scaphirhynchus platorynchus, Cycleptus elongatus,* and *Percina shumardi* may still reside in the two streams, but are not susceptible to capture (Miller and Robison, 1973; Robison and Buchanan, 1988). Fish like *Alosa chrysochloris, Hiodon alosoides, H. terqisus, Hypophthalmichthys molitrix, H. nobilis,* and *Erimyzon sucetta* should have been present, but low numbers likely reduced chance of capture (Beckett and Pennington, 1986; Robison and Buchanan, 1988). *Notropis blennius, N. venustus, N. volucellus, Pimephales notatus, Fundulus chrysotus, F. dispar, Morone chrysops, and Lepomis marginatus* were expected in abundant numbers and are also susceptable to electrofishing as evidenced by the consistent capture of similar species from the same families of the above species, and their absence may indicate recent losses from these drainages (Robison and Buchanan, 1988) (Table 3). Results of Shannon and Margalef diversity indices were similar, and indicate a real change in diversity among stations. Species diversity should be maximized at mid-reach of rivers (fourth to sixth stream order) where microhabitats are most abundant. However, as expected the fish community of Bayou Meto did not recapitulate the River Continuum Concept (RCC), possibly due to contaminants from dioxins, pesticides, and sewage discharge (Platts, 1979; Vannote et al., 1980; Minshall et al., 1983; Schlosser, 1982).

In May, diversity and richness increased as expected between the first two stations at Bayou Meto, and in both May and September at Wattensaw, in accordance with the RCC. Diversity decreased at Station 4 (below dioxin and sewage effluent) and continued at a reduced level to the

Walter Dean Hackathorn, Jr.

Table 2. Fish species composition of Bayou Meto and Wattensaw Bayou, for May, 1991, through September, 1992 (without CPUE for stations). Numbers under stations are the number of individual fish collected for all sample dates. N is the total number of individuals of a species collected from both drainages, and totals are total number of fishes collected at a sample station. Total collection included 7,465 fishes.

TAXA	STATIONS														
Family Species	Above Vertac												Wattensaw Bayou		
	1	2	4	6	7	8	11	12	13	14	15	16	18	20	N
Polyodontidae															
Polyodon spathula														3	3
Lepisosteidae															
Lepisosteus oculatus	5	13	14	46	20	22	7	16	33	35	8	19	8	33	279
Lepisosteus osseus													*4*	*1*	*5*
Lepisosteus platostomas					1		4	4	9	6	4				28
Amiidae															
Amia calva	9	10	1	9	4	4	1	4	6	5		4		9	66
Anguillidae															
Anguilla rostrata														1	1
Clupeidae															0
Dorosoma cepedianum	22	92	13	8	19	16	18	3	38	11	20a	15	13	26	314
Dorosoma petenense												23		55	78
Cyprinidae															*0*
Campostoma anomalum	3													1	4
Ctenopharyngoden idella							1					1			2
Cyprinus carpio	21	24	5	6	35	13	18	6	5	3	10	6	9		161
Hybognathus hayi									1					40	41
Hybognathus nuchalis	1			1					1		1			39	43
Lythrurus fumeus	67			14	4	2	6	11	16		8	7		2	137
Lythrurus umbratilis	53	1	2		1										57
Macrhybopsis storeriana														1	1
Notemigonus crysoleucas	2	5			2				1		1			3	14
Notropis amis						1						1		16	18
Notropis atherinoides					1			1	1	2		1	2	13	21
Notropis buchanani														4	4
Notropis lutrensis											3				3
Notropis maculatus	4	1						1		1		2	3	14	26
Notropis shumardi														4	4
Notropis texanus														31	31
Opsopoeodus emiliae	26	18	2	8	4	7	1		5	6	4	1	8	13	103
Pimephales vigilax											1				1
Catostomidae															0
Carpiodes carpio					2	9		1	1	10	1	13			37
Erimyzon oblongus														1	1
Ictiobus bubalus	1	34	7		5	58		3	1	13	21c	9	7	5	164
Ictiobus cyprinellus	14	35	12	30	18	37	2	1	6	7	59b	3		6	230
Ictiobus niger		3	4		2	5	1				10				25
Minytrema melanops	18	11			2									5	36
Moxostoma macrolepidotum				1											1
Ictaluridae															0
Ameiurus melas													1		1
Ameiurus natalis	1	1												2	*4*
Ictalurus furcatus										2	3	5			10
Ictalurus punctatus		4	4	3	3	2	1	2	11	6	1	24		8	69
Noturus gyrinus	1	1													2
Pylodictis olivaris					2				1						3
Esocidae															0
Esox americanus	11	1	1								1			2	16
Aphredoderidae															0
Aphredoderus sayanus	5	6						1							12
Cyprinodontidae															0
Fundulus notatus	1	2							8						11
Fundulus olivaceus	84	15	3	1	1	3	1	2		1	1	3	11	26	152

Journal of the Arkansas Academy of Science, Vol. 47 [1993], Art. 1

Table 2. Continued:

TAXA	STATIONS														
Family / Species	Above Vertac												Wattensaw Bayou		
	1	2	4	6	7	8	11	12	13	14	15	16	18	20	N
Poeciliidae															
Gambusia affinis	16	8	1	6	4	43	3	2	2		93	19	1	15	213
Atherinidae															0
Labidesthes sicculus	21	24	3	5	2	1			4	4	2		1	21	88
Menidia beryllina	2		4											5	11
Percicthyidae															0
Morone mississippiensis												4		3	7
Morone saxatilis								1							1
Centrarachidae															0
Centrarchus macropterus	6	2													8
Elassoma zonatum		2													2
Lepomis cyanellus	11	3	5	2	1		3	3	8	2	3	1	10	1	53
Lepomis gulosus	31	30	21	62	92	33	24	25	25	16	23	6	33	23	444
Lepomis humilis	2	14	7	29	45	46	25	50	83	119	38	51	32	2	543
Lepomis macrochirus	145	113	113	187	121	109	72	58	104	160	88	48	155	167	1,640
Lepomis megalotis	97	102	120	183	44	12	25	22	172	73	19	50	172	89	1,180
Lepomis microlophus	15	4	8	2	7	9	8	1		3			12	9	78
Lepomis punctatus	8	6	10		3	4	16	10	16	18	6	3	34	6	140
Lepomis symmetricus		2													2
Micropterus punctulatus			2	20					1	9	2	3			37
Micropterus salmoides	24d	10	13	10	5	7	7	6	7	8	74e	3	17	45	236
Pomoxis annularis	12	24	9	12	29	19	24	16	26	14	44	16	6	2	253
Pomoxis nigromaculatus	3	4	1	3	1	3	4	3	12	2	2	4	6	10	58
Percidae															0
Ammocrypta vivax										1					1
Etheostoma asprigene											3			1	4
Etheostoma chlorosomum	1	3						1	1		33				39
Etheostoma gracile		1													1
Etheostoma proeliare	1	1									4		1	2	9
Etheostoma spectabile	5														5
Etheostoma stigmaeum	1														1
Etheostoma shipplei	1														1
Percina caprodes								1	3		3			10	17
Percina maculata	2		1					1		1					5
Sciaenidae															0
Aplodinotus grunniens	1	2		3	24	14	21	6	51	11	1	25	2	8	169
TOTALS	754	632	386	651	504	479	293	262	659	549	595	370	548	783	7,465

a = + 263 fry.
b = 50 juveniles between 28/mm - 68/mm.
c = 18 juveniles between 28/mm - 68/mm.
d = 13 were fry.
e = 71 juveniles between 33/mm - 55/mm.

Table 3. Comparison of fish species collected in 1991 and 1992 from bayous Meto and Wattensaw (without CPUE for the two drainages). Species collected in Bayou Meto and/or in Watensaw Bayou are denoted by X. Species historically reported from these drainages but not collected in this study are listed and followed by an asterisk but not marked. Rare species are those collected only once from a station or so designated in the literature, and are denoted by an X. Species difficult to capture by my sample methods are so designated; and species not recorded from these drainages but collected are designated by two asterisks.

Species	Bayou Meto	Wattensaw Bayou	Rare species	Difficult to collect
Scaphirhynchus [;atprumcjis			X	X
Polyodon spathula		X		X
Lepisosteus osseus		X		
Lepisosteus platostomus	X			
Anguilla rostrata		X	X	
Alosa chrysochloris *			X	X
Campostoma anomalum **	X	X		
Ctenoparyngoden idella	X			
Cyprinus carpio	X			
Hiodon alosoides *			X	
Hiodon tergisus *			X	
Hybognathus hayi **	X	X		
Hypophthalmichthys molitrix			X	
Hypophthalmichthys nobilis			X	
Lythrurus umbratilis **	X			
Macrhybopsis storeriana		X	X	
Notropis blennius *				
Notropis buchanani		X		
Notropis lutrensis	X		X	
Notropis shumardi **		X	X	
Notropis texanus **		X		
Notropis venusthus *				
Notropis volucellus *				
Pimephales notatus *				
Pimephales vigilax	X		X	
Carpoides carpio	X			
Cycleptus elongatus *				
Erimyzon oblongus **		X	X	
Erimyzon sucetta		X	X	
Ictiobus niger	X			
Moxostoma macrolepidotum	X		X	
Ameiurus melas		X	X	
Ictalurus furcatus	X		X	
Noturus gyrinus	X			
Pylodictis olivaris	X			
Aphredoderus sayanus	X			
Fundulus chrysotus *				
Fundulus dispar *				
Fundulus notatus	X			
Morone chrysops *				
Morone saxatilis	X		X	
Centrarchus macropterus	X			
Elassoma zonatum	X		X	
Lepomis marginatus				
Lepomis symmetricus	X		X	
Micropterus punctulatus	X			
Ammocrypta vivax **	X		X	X
Etheostoma chlorosomum	X			X
Etheostoma gracile	X		X	X
Etheostoma spectabile **	X		X	X
Etheostoma stigmaeum **	X		X	X
Etheostoma whipplei **	X		X	X
Percina maculata **	X			X
Percina shumardi *				X

last station. Declines along a gradient in which diversity and richness should increase are indicative of disturbance (Diamond and Gilipin, 1980; Angermeir and Schlosser, 1989). The fish community of Bayou Meto appears to be impacted at Station 4, and community structure remained variable and unpredictable through the last sample station.

The 1992 sampling regime showed Wattensaw Bayou to have higher diversity and richness when compared to Bayou Meto. The highest diversity and most species collected for all sample dates was at Station 20 on Wattensaw Bayou. However, when examining total fish species collected for 1991 (without CPUE) and 1992 Bayou Meto has more species than Wattensaw Bayou. Bayous Meto and Wattensaw are both well represented by the total number of species. Difference in the two streams may be due to differential sampling efforts. Most likely, the total number of species in Wattensaw would have exceeded Bayou Meto if a similar sampling effort had been used (same number of sampling stations and sampling days). For example, absence of *C. carpio* from Wattensaw likely was an artifact of this differential sampling.

Bayou Meto is an impacted stream below the confluence of Rocky Branch. Dioxins and/or pesticide contamination appear to be the most likely reasons for declines in fish diversity in Bayou Meto, although sewage effluent and pesticides could also contribute significantly to these declines as a singular agent or in synergism. Fish taxa were missing from this survey, and loss of species due to the above anthropomorphic alterations is possible, and is deserving of future investigation. Wattensaw Bayou and stations 1 and 2 on Bayou Meto proved high in fish diversity and followed the RCC model.

Acknowledgements

This research has been supported by grants from the U.S. Fish and Wildlife Service and the U.S. Environmental Protection Agency, with technical support by the Arkansas Cooperative Fish and Wildlife Research Unit, the Arkansas Game and Fish Commission, and University of Arkansas at Fayetteville. Helpful manuscript suggestions were contributed by Dr. James E. Johnson, Dr. Arthur V. Brown, and Dr. William G. Layher; and invaluable field collection assistance came from Dr. James E. Johnson, Dr. William G. Layher and his field assistants at U of A Pine Bluff, Andrew L. Thompson, Steve Marchant, and Roseanne Barnhill. Thanks to my lovely wife who helped whenever possible.

Literature Cited

ADPC&E. 1984. Arkansas Department of Pollution Control and Ecology. Monitoring Rocky Branch at East Main Street: Ref: Permit #2713 WR-1 memorandum to water files from Frank Stephens.

ADPC&E. 1989. Monitoring Rocky Branch at East Main Street: Ref: Permit #2713 WR-1 Memorandum to Water files.

Angermeir, P.L. and **I.J. Schlosser.** 1989. Species-area relationships for stream fishes. Ecology 70:1450-1462.

Beckett, D.C. and **C.H. Pennington.** 1986. Water quality, macroinvertebrates, larval fishes, and fishes of the lower Mississippi River: a synthesis. Tech. Rept. E-86-12. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Boyle, T.P., G.M. Smillie, J.C. Anderson and **D.R. Beeson.** 1990. A sensitivity analysis of nine diversity and seven similarity indices. Res. J. WPCF 6:749-762.

Diamond, J. and **M.E. Gilipin.** 1980. Turnover noise: contribution to variance in species number and predictions from immigration and extinction curves. Am. Nat. 115:884-889.

Heckathorn, W.D. Jr. 1993. 2, 3, 7, 8-Tetrachlorodibenzo-p-dioxin in Bayou Meto and the ecology of a contaminated stream in east central Arkansas. Master Thesis. University of Arkansas.

ITC. 1987. Sampling and analytical program plan Vertac offsite areas. International Technology Corporation. Knoxville, Tennessee. 85 pp.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. Mcallister and **J.R. Stauffer, Jr.** 1980. Atlas of North American Freshwater Fishes. North Carolina State Mus. Nat. Hist., Raleigh, North Carolina. 867 pp.

Margalef, R. 1963. On certain unifying principles in ecology. Am. Natur. 97:357-374.

Margalef, R. 1958. Information theory in ecology. Gen. systems 3:36-71.

Miller, R.G. and **H.W. Robison.** 1973. The fishes of Oklahoma. Oklahoma State University Museum of Natural and Cultural History. Series No. 1. 246 pp.

Minshall, G.W., R.C. Peterson, K.W. Cummins, T.L. Bott, J.R. Sedell, C.E. Cushing and **R.L. Vannote.** 1983. Interbiome comparison of stream ecosystem dynamics. Ecol. Monogr. 53:1-25.

Neely, B.L. 1985. Water-surface profiles along Bayou Meto and Rocky Branch near Jacksonville, Arkansas: U.S. Geological Survey Openfile Report 85-176. 12 pp.

Nielson, L.A. and **D.L. Johnson.** 1985. Fisheries techniques. American Fisheries Society Bethesda, Maryland. 468 pp.

Novotny, D.W. and **G.R. Priegel.** 1974. Electrofishing boats: improved designs and operational guidelines to increase the effectiveness of boom shockers.

Wisconsin Dep. Nat. Res. Tech. Bull. 73. 48 pp.

Owens, T.G. and **J.R. Karr.** 1978. Habitat structure and stream fish communities. Ecology 59:507-515.

Platts, W.S. 1979. Relationships among stream order, fish populations, and aquatic geomorphology in an Idaho river drainage. Fisheries 4:5-9.

Robins, R.C., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea and **W.B. Scott.** 1991. Common names of fishes from the United States and Canada. Fifth Edition. Am. Fisheries Soc. Spec. Pub. 20. 183 pp.

Robison, H.W. and **T.M. Buchanan.** 1988. Fishes of Arkansas. The University of Arkansas Press. 563 pp.

Schlosser, I.J. 1982. Fish community structure and function along two habitat gradients in a headwater stream. Ecol. Monogr. 52:395-414.

Shannon, C.E. 1948. A mathematical theory of communication. Bell System Tech. J. 27:379-423, 623-656.

USEPA. 1990. Quarterly status report of superfund sites in region 6, state of Arkansas. 7 pp.

USEPA. 1991. Vertac site update: An update on activities at the Vertac Superfund site. EPA Region 6. Haz. Waste Div. 9 pp.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and **C.E. Cushing.** 1980. The river continuum concept. Can. J. Fish. Aquat. Sci. 37:130-137.

Vibert, R. 1967. Fishing with electricity – its applications to biology and management. Fishing News (Books) Ltd., London. 276 pp.

Washington, H.G. 1984. Diversity, biotic and similarity indices a review with special relevance to aquatic ecosystems. Water Resour. 18:653-694.

Ichthyofauna of the Village Creek System

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Abstract

Village creek is a lowland stream lying in the Mississippi Embayment in Randolph, Lawrence and Jackson counties in northeastern Arkansas. The stream has been channelized in Randolph and Lawrence counties as have most of its tributaries. The Jackson County portion of the stream has not been channelized. Twelve sites were sampled seasonally by seining along Village Creek and its tributaries. In addition to seasonal work, six sites were sampled from one to three times each by several methods. A total of 8000 specimens was collected by all means used (7754 at seasonal sites and 246 at supplemental sites). Forty-two species were collected from 16 families. Two species not previously reported from the System were collected in this study namely *Hiodon alosoides* and *Pimephales vigilax*. All 42 of the species collected in the study were represented in Jackson County while only 24 species were collected in Lawrence and Randolph counties. Members of the family Centrarchidae were the most commonly collected group (44% of specimens) whereas the most commonly collected species was *Gambusia affinis* (29.6% of specimens). Some of the fish species in the System have shown resilience to stream alteration, domestic sewage, industrial and agricultural runoff and dumping of refuse. However, the future success of some species (e.g., *Opsopoeodus emiliae, Notropis maculatus, Notropis texanus, Lythrurus fumeus, Elassoma zonatum* and *Etheostoma gracile*) will depend on the protection of and sustainable use of the natural resources in the watershed.

Introduction

The Village Creek System lies within the Mississippi Alluvial Plain, as defined by Foti (1974). The alluvial deposition of sand, gravel and clay, which began prior to the Pleistocene, continues today. The soil is deep but almost impermeable, and drainage is poor. Natural vegetation is composed of primarily various bottomland hardwoods, which are adapted to wet, poorly drained soils (Foti, 1974).

Village Creek originates approximately 6 km north of O'Kean in Randolph County and meanders southwesterly through Lawrence County to its confluence with the White River south of Newport in Jackson County. The stream is approximately 88.5 km in length, while the basin's greatest width is 8.2 km (Beadles, 1977). Its watershed lies primarily in Randolph, Lawrence and Jackson counties, but small portions lie within Craighead and Greene counties (Beadles, 1974).

The entire length of Village Creek has been channelized in Randolph and Lawrence counties, as have most of its tributaries. The sparse timber remaining within the watershed occurs as isolated stands along the immediate banks. Some tributaries have been denuded completely. Channelization has been financed and conducted by private landowners, drainage districts and the U.S. Army Corps of Engineers (USACE) (Beadles, 1974). The immediate vicinity of the stream in Jackson County is quite different. Plans to channelize this portion of Village Creek have not been consumated as yet, and fairly extensive tupelo-cypress swamps still remain. In addition to stream channelization, the system has been and continues to be subjected to domestic sewage, chemical runoff (e.g. toxaphene from the 1950's through the 1970's) and industrial effluents, the latter particularly in Jackson and Lawrence counties. These have caused periodic fish kills of varying severity (Beadles, 1977). In this study a spill of diesel fuel was observed in Lawrence County, and a fish kill, which occurred at the St. Hwy. 90 bridge in Randolph County, was probably due to oxygen depletion resulting from a heavy organic load and low water levels.

Black (1940) first surveyed the fishes of Village Creek. He reported 12 species from four sites. The Arkansas Game and Fish Commission (Baker, 1953) has infrequently sampled the sport and commercial fisheries. Beadles (1974, 1977) conducted environmental inventories in which most flora and fauna were evaluated. However, none of these studies examined the stream system comprehensively, and no seasonal data were gathered. Further, continued environmental alteration may have impacted the previously documented status of some fish species within the system.

The primary goal of this study was to establish a current species list for the Village Creek System. Secondary goals were to determine the relative abundance and spatial and seasonal distribution of those species.

Methods and Materials

Twelve sites were selected for seasonal collections on the main stem and tributaries (Fig. 1). They were chosen in many instances because they had served as sites for previ-

ous studies (Beadles, 1974, 1977 and Looney, unpub.). A description of the sites is as follows:

1. Randolph Co. T18N R2E S27&28 (section line). Approx. 3.2 km NW of O'Kean. Trib.
2. Lawrence Co. T17N R1E S5. Village Creek approx. 3.2 km NE of Walnut Ridge.
3. Lawrence Co. T16N R1E S5. Village Creek 0.8 km W of Hoxie on U.S. 63 and below confluence of Coon Creek.
4. Lawrence Co. T15N RIW S1. Village Creek at the St. Hwy. 228 crossing at the westernmost city limits of Minturn.
5. Lawrence Co. T15N R1W S34. Village Creek at the St. Hwy. 230 crossing approx. 0.8 km E of Alicia.
6. Jackson Co. T13N R1W S31. Guffy (Guthrie) Lake on Village Creek 4.8 km E of Tuckerman on St. Hwy. 37.
7. Jackson Co. T11N R2W S7. Village Creek at the St. Hwy. 14 crossing approx. 0.8 km SE of Newport.
8. Lawrence Co. T17N R1E S22&23. Coon Creek approx. 1.6 km N of Walnut Ridge on U.S. 67.
9. Lawrence Co. T16N R1E S15. White Oak Slough approx. 1.6 km SE of Hoxie.
10. Lawrence Co. T15N R1E S12. Lick Pond Slough approx. 8 km ESE of Minturn and 1.6 km N of Jct. of St. Hwys. 91 and 228.
11. Jackson Co. T13N R3W S36. Hout Ditch approx. 4.8 km W of Tuckerman on St. Hwy. 226 then approx. 0.6 km S.
12. Jackson Co. T12N R2E S33. Locust Creek at the Newport Industrial Park (Newport Airbase).

Forty-two of the anticipated 48 samples were obtained. Sites 2, 3 and 4 were not sampled during the fall, and sites 7, 11 and 12 were not sampled during the winter because of high water. Some channelized sites were virtually impossible to seine during periods of high water because of water depth and current velocity.

Seasonal samples were obtained by use of two seines. The seines were 6 m x 2 m with 3 mm mesh and 15 m x 1.2 m with 6 mm mesh and both seines were constructed with delta type netting. Attempts were made to seine one man-hour at each site per season. At some sites this was enough time to sample all of the specimens for a considerable distance, especially when low-water conditions existed.

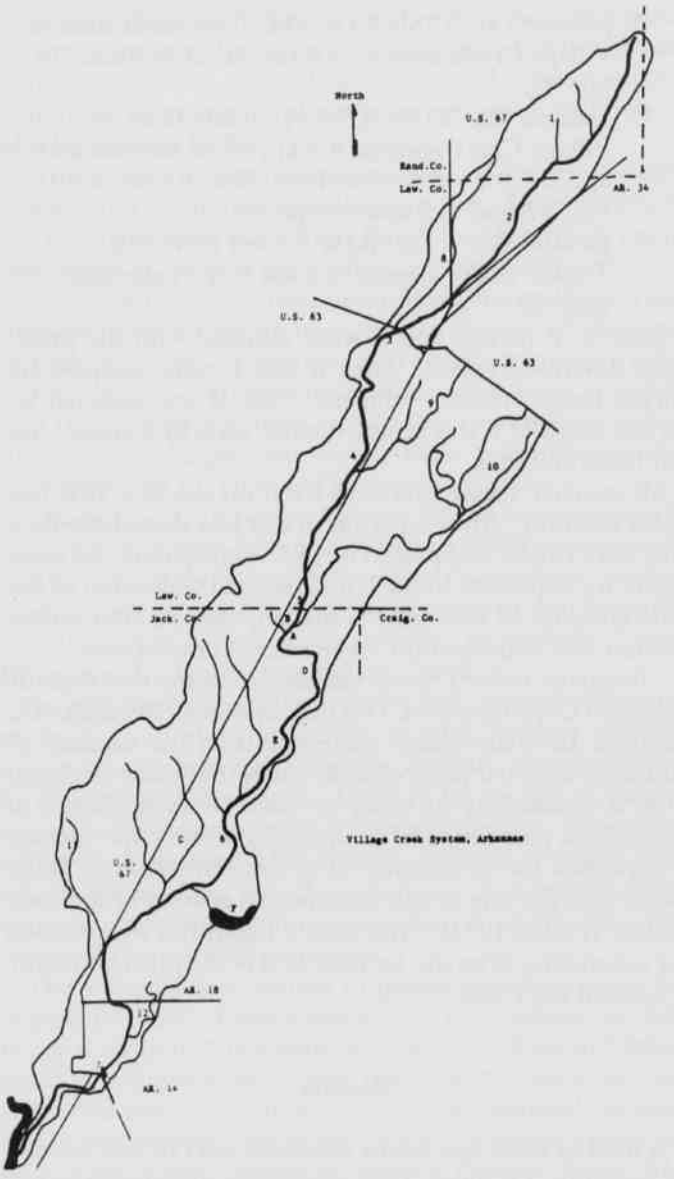

Fig. 1. The Village Creek System.

In addition to the seasonal sites, six supplemental sites were selected to more thoroughly survey Jackson County. Their locations are as follows:

A. Jackson Co. T14N R1W S4&8. Approx. 6.4 km NE of Swifton then 0.6 km E on section road. Trib. 12 Oct. 91.
B. Jackson Co. Same as above except Village Creek at mergence of above site. 12 and 19 Oct. 91 and 10 April 92.
C. Jackson Co. T13N R2W S26. Swan Pond Slough approx 0.8 km E of Tuckerman on St. Hwy. 37. 7 Dec. 91.

D. Jackson Co. T13N R1W S14. Two small lakes on Village Creek approx. 4.8 km NE of Swifton. 11 Jan. 92.

E. Jackson Co. T13N R1W S4. Holly Lake on Village Creek approx. 3.2 km SE of Swifton and approx. 0.4 km S of St. Hwy. 226. 31 Jan. 92, 1 Feb. 92 and 4, 5 and 6 Sept. 92.

F. Jackson Co. T12N R1W S7 and R2W S12. Tupelo Brake approx. 6.4 km S of Tuckerman. 29 Aug. 92.

Sites A, B (twice) and C were sampled with the previously described seines. Sites B and F were sampled by Turtox Indestructible™ dip net. Site D was sampled by gill net and Site E was sampled twice each by trammel net and hook and line.

All voucher specimens were fixed on site in a 10% formalin solution. After a period of not less than three days they were rinsed and placed in 40% isopropanol. All specimens are deposited in the Ichthyological Collection of the ASU Museum of Zoology. Some large fishes, after identification and enumeration, were released due to size.

Diversity indices were calculated using the Aquatic Ecology-PC program of Oakleaf Systems, Decorah, IA. Simpson Diversity Index corresponds to the number of randomly selected pairs of individuals that must be drawn from a community in order to have an even chance of obtaining a pair with both individuals of the same species. It expresses the dominance of or concentration of abundance into the one or two commonest species of the community (Poole, 1974). The base 2 logarithm was selected for calculating diversity indices, as it is the most commonly utilized log (Cox, 1985).

Results

A total of 8000 specimens was collected (16 families and 42 species). Of these, 7754 specimens were taken at seasonal sites (1-12), while 246 came from supplemental sites (A-F). The most abundant family was Centrachidae, while Poeciliidae, although represented by a single species (*Gambusia affinis*), was second numerically. Two species not previously known for the System were also collected. *Hiodon alosoides* was collected once, during the summer (Site 7), and *Pimephales vigilax* was collected during the summer (Sites 6 and 12), winter (Sites 4 and 6) and spring (Site 6). These records increase the number of species recorded for the Village Creek System to 62 (Table 1).

Table 1. Ichthyofauna of the Village Creek System.

	Scientific Name	Common Name
	Polyodon spathula (Walbaum)	paddlefish
	Atractosteus spatula (Lacepede)	alligator gar
*	*Lepisosteus oculatus* (Winchell)	spotted gar
	Lepisosteus osseus (Linnaues)	longnose gar
*	*Lepisosteus platostomus* Rafinesque	shortnose gar
*	*Amia calva* Linnaeus	bowfin
	Anguilla rostrata (Lesueur)	American eel
	Alosa chrysochloris (Rafinesque)	skipjack herring
*	*Dorosoma cepedianum* (Lesueur)	gizzard shad
***	*Hiodon alosoides*	goldeye
*	*Esox americanus* Gmelin	grass pickerel
	Esox niger Lesueur	chain pickerel
	Ctenopharyngodon idella (Valenciennes)	white amur
	Cyprinella venusta (Girard)	blacktail shiner
*	*Cyprinus carpio* Linnaues	common carp
*	*Hybognathus nuchalis* Agassiz	silvery minnow
*	*Lythrurus fumeus* Evermann	ribbon shiner
*	*Notemigonus crysoleucas* (Mitchell)	golden shiner
*	*Notropis atherinoides* Rafinesque	emerald shiner
	Notropis boops Gilbert	bigeye shiner
*	*Notropis maculatus* (Hay)	taillight shiner
*	*Notropis texanus* (Girard)	weed shiner
	Notropis umbratilis (Girard)	redfin shiner
	Notropis volucellus (Cope)	mimic shiner
*	*Opsopoeodus emilae* (Hay)	pugnose minnow
**	*Pimephales vigilax* (Baird and Girard)	bulhead minnow
*	*Ictiobus bubalus* (Rafinesque)	smallmouth buffalo
*	*Ictiobus cyprinellus* (Valenciennes)	bigmouth buffalo
*	*Ictobus niger* (Rafinesque)	black buffalo
*	*Minytrema melanops* (Rafinesque)	spotted sucker
	Moxostoma duquesnei (Lesueur)	black redhorse
*	*Ameiurus melas* (Rafinesque)	black bullhead
*	*Ameiurus natalis* (Lesueur)	yellow bullhead
	Ictalurus furcatus (Lesueur)	blue catfish
*	*Ictalurus punctatus* (Rafinesque)	channel catfish
*	*Noturus gyrinus* (Mitchell)	tadpole madtom
	Noturus nocturnus Jordan	freckled madtom
	Pylodictis olivaris (Rafinesque)	flathead catfish
*	*Aphredoderus sayanus* (Gilliams)	pirate perch
*	*Fundulus olivaceus* (Storer)	blackspotted topminnow
*	*Gambusia affinis* (Baird and Girard)	mosquitofish
*	*Labidesthes sicculus* (Cope)	brook silverside
	Morone chrysops (Rafinesque)	white bass
	Morone mississippiensis Jordan & Eigenmann	yellow bass
*	*Lepomis cyanellus* Rafinesque	green sunfish
*	*Lepomis gulosus* (Cuvier)	warmouth
*	*Lepomis humilus* (Girard)	orangespotted sunfish
*	*Lepomis macrochirus* Rafinesque	bluegill
*	*Lepomis megalotis* (Rafinesque)	longear sunfish
*	*Lepomis microlophus* (Gunther)	readear sunfish
*	*Lepomis punctatus* (Valenciennes)	spotted sunfish
*	*Micropterus punctulatus* (Rafinesque)	spotted bass
*	*Micropterus salmoides* (Lacepede)	largemouth bass
*	*Pomoxis annularis* Rafinesque	white crappie
*	*Pomoxis nigromaculatus* (Lesueur)	black crappie
*	*Elassoma zonatum* Jordan	banded pygmy sunfish
	Etheostoma asprigene (Forbes)	mud darter
	Etheostoma blennioides Rafinesque	greenside darter
*	*Ethesotoma chlorosomum* (Hay)	bluntnose darter
*	*Ethesotoma gracile* (Girard)	slough darter
	Etheostoma proeliare (Hay)	cypress darter
*	*Aplodinotus grunniens* Rafinesque	freshwater drum

* = collected in this study
** = collected in this study but first by Looney (unpubl.)
*** = collected in this study and new to the system

Most fishes were collected during the summer (31 species, 4601 specimens), while the fewest individuals were collected during the winter (18 species, 525 specimens). Fall (19 species, 1176 specimens) and spring (28 species, 1353 specimens) were intermediate in values. Both Simpson and Shannon-Wiener diversity index values reflected this pattern.

All 42 species collected in the study were taken in Jackson County, but only 24 of these species were recorded from Randolph and Lawrence counties (24 counting several dead freshwater drum at the St. Hwy. 90 fish kill). The four seasonal sites in Jackson County (6, 7, 11, 12) collectively yielded 38 species, while the eight sites (1-5, 8-10) in Randolph and Lawrence counties had but 23 species (Table 2). More specifically, the two main stem sites in Jackson County (6, 7) supported 55% more fish species than the main stem sites (2-5) in Randolph and Lawrence counties, and the two Jackson County tributary sites (11, 12) supported 47% more fish species than did the four tributary sites (1, 8-10) in Randolph and Lawrence counties (Table 3). When the results of the supplemental samples are included, the six main stem and four tributary sites in Jackson County collectively yielded 38 and 25 species, while the four main stem and four tributary sites in Randolph and Lawrence counties had but 20 and 17 species, respectively. Diversity index values were also greater in Jackson County (Table 3).

Fourteen species were collected only in Jackson County: *Lepisosteus osseus, Lepisosteus platostomus, Hiodon alosoides, Hybognathus nuchalis, Lythrurus fumeus, Notropis texanus, Minytrema melanops, Aphredoderus sayanus, Labidesthes sicculus, Lepomis humilus, Lepomis punctatus, Micropterus punctulatus, Elassoma zonatum* and *Etheostoma gracile*. Conversely, no species were found only in Randolph and/or Lawrence counties. However, the only freshwater drum recorded from Randolph and Lawrence counties were from the previously mentioned fish kill.

Discussion

Black (1940) reported 12 species from four sites in the Village Creek System, all of which are still fairly common. However, since Beadle's (1977) investigation there appears to have been a moderate decline in species diversity (Tables 4, 5). Most of the fish species reported by Beadles (1977) but not collected in this study (e.g. *Polyodon spathula, Atractosteus spatula*) are big river forms which periodically invade the lower Village Creek System from the White River. These species are least likely to be captured by methods used in this study. Nevertheless, in 1977 the most abundant fish species formed less than 50% of the total community, but they now account for over 70% of fishes collected. Further, panfishes have been displaced by the mosquitofish (Table 4). This species has broad ecological tolerances and, when introduced, almost always eliminates most or all of the smaller native fishes (Robison and Buchanan, 1988).

The effects of environmental degradation are further emphasized when the fish collections from Jackson County are compared with those from Randolph/Lawrence counties (Table 3). Despite the smaller sampling effort (two stations vs. five), by every measure utilized, the main stem stations in Jackson County have a more diverse, stable community structure. Comparisons of tributary stations yield similar results. All tributary stations have been channelized, but the two stations in Jackson County have more diverse assemblages because of their proximity to the unchannelized (in Jackson County) main stem.

Village Creek supports a diverse fish fauna, particularly for a deltaic stream. Mauney and Harp (1979) reported 42 and 32 species for Bayou DeView and Cache River, respectively. These streams are just to the east of and basically parallel Village Creek. Both streams, particularly Cache River, are also larger than Village Creek.

Several environmentally sensitive fish species still occur at least in limited numbers in this stream system. *Atractosteus spatula* and *Poloyodon spathula* are considered by Robison and Buchanan (1988) to be species of special concern. *Opsopoeodus emiliae, Elassoma zonatum, Etheostoma asprigene, Etheostoma chlorosomum, Etheostoma gracile* and *Etheostoma proeliare* are all declining in eastern Arkansas because environmental perturbation is decreasing the extent of their preferred habitat.

The Village Creek System in particular continues to be degraded today. Channelization is in progress as this paper is written. More natural cover (woodlots and fence rows) is being removed, with subsequent erosion of topsoil. Solid wastes, including agricultural chemical containers, are widespread and, at least locally, profuse. As recently as 1984 Victor Industries, Revere Copper Brass, AM Lantern, Diaz Refinery and the cities of Swifton, Tuckerman, Hoxie and Walnut Ridge had NPDES permits to dump various effluents into Village Creek and its tributaries (ADPCE, 1984). Precise impacts of these events are not yet clear.

This study clearly reveals that the Village Creek System harbors a diverse ichthyofauna, but that diversity is being eroded. If the environmental degradation is not reversed in the near future, the stream shall become like most other streams in the Mississippi Alluvial Plain, devoid of nearly all but the most tolerant species.

Table 2. Species Distribution within Seasonal Samples

Species	Sites												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Lepisosteus oculatus							4						4
Lepisosteus platostomus							2						2
Dorosoma cepedianum		26	63	4	8	33	11	414	32	5		9	605
Hiodon alosoides							1						1
Esox americanus										2			2
Cyprinus carpio	1		1					9					11
Hybognathus nuchalis						1	49					611	611
Notemigonus crysoleucas	7		1			3		3	2	2	131	18	167
Lythrurus fumeus												33	33
Notropis atherinodes				5			5	2		1		29	42
Notropis maculatus					2	13							15
Notropis texanus											5		5
Opsopoeodus emiliae					7	18	4				6		35
Pimephales vigilax				1		8						2	11
Ictiobus bubalus						2	4	2					8
Ictiobus niger		2	54				2						58
Minytrema melanops						1	3					3	7
Ameiurus melas	6							2	1		1	1	11
Ictalurus punctatus		30	2	7				1					40
Aphredoderus sayanus							1				1		2
Fundulus olivaceus					16	14	11				204	2	246
Gambusia affinis	942	29	361	1	57	10	33	180	303	105	202	132	2355
Labidesthes sicculus							4						4
Lepomis cyanellus	472	13	2	5	416	30		37	233	32	98	52	1390
Lepomis gulosus	3	1	1	1	5	2	5		10	1	22	7	58
Lepomis humilus							1						1
Lepomis macrochirus	12	79	31	10	117	68	23	533	150	13	170	151	1357
Lepomis megalotis		62	21	12	20	49	1	1	91	13	101	89	461
Lepomis microlophus							4		10				14
Lepomis punctatus						3							3
Micropterus punctulatus												1	1
Micropterus salmoides		1	1	3	4		1				1		11
Pomoxis annularis		9	6	2	11	3	6	23		3	14		77
Pomoxis nigromaculatus	2					2	4	3			2	2	15
Elassoma zonatum							1						1
Etheostoma chlorosomum			1	2	9	6	1		1	4	5	4	33
Etheostoma gracile						1	1				4		6
Aplodinotus grunniens						1							1
Notropis sp.							6						6
Total	1443	254	545	54	672	269	183	1210	833	181	962	1149	7754

Table 3. Comparison of Seasonal Sites in Jackson County vs. Non-Jackson County

	Main Stem		Tributaries	
	Jack.	Rand./Law.	Jack.	Rand./Law.
Total No. Taxa	31	20	23	17
Mean No. Taxa	22	12	16	11
Mean No. Ind.	226	382	1056	917
Mean Simp. Div.	0.866	0.699	0.759	0.627
Mean Shan. Div.	3.430	2.354	2.590	1.736
Mean Hmax'	4.417	3.612	4.043	3.165

Table 4. Dominant Fish Species (%).

Beadles (1977)	Looney (unpub)*	This Study
Lepomis macrochirus (15)	*Gambusia affinis* (70)	*Gambusia affinis* (29)
Lepomis cyanellus (13)	*Lepomis macrochirus* (12)	*Lepomis cyanellus* (17)
Notropis texanus (11)	*Etheostoma chlorosomum* (3)	*Lepomis macrochirus* (17)
Gambusia affinis (10)		*Hybognathus nuchalis* (8)

*Collections were made during October 1988 and January 1989.

Table 5. Comparative H' values.

Station-Season	Beadles (1977)	Looney (unpub)	This Study
1-winter	1.831	1.023	
4-summer	2.681	–	2.000
4-fall	1.712	2.873	–
4-winter	2.226	2.658	2.873
6-summer	3.542	–	2.817
6-fall	3.011	2.442	2.930
6-winter	2.540	–	2.232
7-summer	3.506	–	3.285

Literature Cited

ADPCE. 1984. Water quality inventory report. Arkansas Dept. Poll. Cont. Ecol. Little Rock. 495 pp.

Baker, R. 1953. Unpublished stream survey of Village Creek. Arkansas Game and Fish Commission. 3 pp.

Beadles, J.K. 1984. Fishes. *In* Environmental inventory of the Village Creek Watershed. United States Army Corps of Engineers, Little Rock District. Little Rock, Arkansas. 74 pp.

Beadles, J.K. 1977. Fishes. *In* Environmental inventory of the Village Creek Watershed. United States Department of Agriculture Soil Conservation Service. Little Rock, Arkansas. 61 pp.

Black, J.D. 1940. Distribution of the fishes of Arkansas. Unpub. Ph.D. dissertation, University of Michigan. 243 pp.

Cox, G.W. 1985. Laboratory manual of general ecology. 5th Ed. Wm. C. Brown Co., Dubuque, IA. 248 pp.

Foti, T.L. 1974. Natural divisions of Arkansas. *In* Arkansas natural area plan. Arkansas Department of Planning. 248 pp.

Looney, R. undated. Unpublished stream survey of Village Creek.

Mauney, M. and **G. Harp.** 1979. The effects of channelization on fish populations of the Cache River and Bayou DeView. Proc. Ark. Acad. Sci. 33:51-54.

Poole, R.W. 1974. An introduction to quantitative ecology. McGraw-Hill Book Co. New York, NY. 523 pp.

Robison, H.W. and **T.M. Buchanan.** 1988. Fishes of Arkansas. University of Arkansas Press, Fayetteville, Arkansas. 536 pp.

Environmental Analysis of the Caddo River and its Tributaries: Comparison of Water Quality During 1992 with 1974-75

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Abstract

Environmnetal data related to water quality of the Caddo River and its tributaries were collected from March - October, 1992, and compared with data from August, 1974 - May, 1975. Bacterial, chemical and physical parameters were investigated at six river locations and thirteen tributary sites. Ammonia, nitrates, soluble phosphorus, turbidity and fecal coliform were signficantly lower, and sodium and postassium were significantly higher in 1992 than during the previous study. Bacterial loading exceeded EPA criteria at some locations during both studies.

Introduction

Environmental data related to water quality of the Caddo River and its tributaries were collected form March - October, 1992, and compared with a previous study from August, 1974 - May, 1975 (Nix et al., 1975). The Caddo River above DeGray Reservoir drains a portion of the southeastern flank of the Ouachita Mountains in southwest Arkansas. There are two wastewater facilities, several chicken houses, a barite mine and septic drainages located on the watershed, as well as non-point sources such as grazing livestock.

In recent years considerable concern has been shown for the quality of Arkansas waterways. In 1989 it was reported that almost one-fourth of the miles of streams in the state have impaired quality due to pollution (Ridlehoover, 1992). This study was directed toward determination of current water quality of the Caddo River system, and elucidation of any changes which have occured in quality since the mid-1970s.

Methods and Materials

Study sites are listed in Table 1. Bacterial parameters included enumeration of total coliforms (TC), fecal coliforms (FC) and fecal streptococci (FS). Chemical and physical parameters included soluble phosphorous, ammonia, nitrates, sulfates, chloride, manganese, sodium, potassium, iron, calcium, magnesium, alkalinity, pH, conductivity and turbidity.

Samples were collected an analyzed according to standard methods (American Public Health Association, 1989). Bacterial analyses were by membrane filtration on mEndo (TC), mFC (FC) and mEnterococcus (FS) media (Difco). A 500 ml raw water sample was collected for testing pH, turbidity, alkalinity and conductivity. Approximately 2 ml of 1:1 hydrochloric acid was added to a 250 ml sample of water for analyses of soluble phosphorus and ammonia. A 175 ml filtered sample was used for analyses of chloride, sulfates and nitrates. A 20 ml sample was acidified with 2 ml of concentrated sulfuric acid for determination of iron, clacium, sodium, potassium, magnesium and manganese.

Table 1. Location of sampling stations for the Caddo River, Arkansas

River Stations	River Tributaries
Black Springs	Beech Creek
Norman	Polk Creek
Caddo Gap	Lick Creek
Glenwood	Huddleston Creek
Amity	Collier Creek
Highway 84	Smith Creek
	Gap Creek
	Mill Creek
	South Fork Caddo River
	Mudlick Creek
	Sweetwater Creek
	Rock Creek
	Caney Creek

The data were analyzed by use of the Statistical Analysis System (SAS). Analysis of variance (ANOVA) was used to evaluate differences in physio-chemical and bacteriological parameters. When significant, Tukey-Kramer tests (Sokal and Rohlf, 1981) were used to determine which locations was different. Two-way ANOVA was used to evaluate variations due to year of sample and location

Journal of the Arkansas Academy of Science, Vol. 47 [1993], Art. 1

of sample.

Results and Discussion

Data from the river sites collected during 1992 were averaged and compared to that of 1974-75 (Table 2). Ammonia, nitrates, soluble phosphorus, turbidity and fecal coliform were significantly lower, and sodium and potassium were significantly higher in 1992. Alkalinity and conductivity were significantly higher in the upper river. Previous studies have noted the presence of limestone in the upper watershed, and its absence in the lower reaches of the river (Nix et al., 1975). Therefore, dilution by the tributaries tend to occur in the lower regions of the river.

The means of the physio-chemical and bacteriological parameters measured for the entire river were compared to Enviromental Protection Agency (EPA) quality criteria (EPA, 1986). The values for these parameters were within EPA criteria except for 9% of the samples of fecal coliform.

Table 2. Physio-chemical and bacteriological data from Caddo River stations. *Significant differences between years (0.05 level)

Variable	1992 No. samples	1992 Mean/Std. Dev.	1974-75 No. samples	1974-75 Mean/Std. Dev.
chloride (mg/L)	42	1.77/0.34	na	na
pH	42	7.44/0.30	42	7.38/0.19
ammonia (mg/L)*	42	0.06/0.03	42	0.11/0.06
manganese (ug/L)	42	0.07/0.02	na	na
alkalinity (mg/L)	42	49.0/10.3	42	45.4/10.6
nitrates (mg/L)*	41	0.10/0.07	42	0.17/0.18
conductivity	42	107.0/19.2	42	106.2/29.3
phosphorus (ug/L)*	36	0.02/0.008	42	0.03/0.06
sodium (mg/L)*	42	2.22/0.87	42	1.19/0.34
sulfates (mg/L)	42	5.16/0.67	na	na
potassium (mg/L)*	42	0.92/0.17	42	0.59/0.35
iron (mg/L)	41	0.59/0.19	na	na
calcium (mg/L)	42	16.3/4.45	36	15.19/5.14
magnesium (mg/L)	42	1.81/0.35	30	1.82/0.40
turbidity*	42	2.25/1.20	30	4.30/3.76
FC (cfu/100ml)*	47	58/882	48	861/1202
FS (cfu/100ml)	48	173/380	na	na
TC (cfu/100ml)	35	17312/8390	na	na

na = not available

The data from each specific sampling stie were grouped and compared with EPA recommendation. All chemical and physical parameters were within EPA criteria. However, fecal coliform bacteria surpassed EPA criteria at Black Springs (25% of samples) and at Glenwood (13% of samples) (Table 3).

Table 3. Bacterial data from river stations. EPA criterion for Fecal Coliforms=200/100ml. *Some samples exceeded EPA criterion.

Site	Variable	No. Samples	Mean/Standard Deviation
Black Springs	FC	8	109.125*
	FS	8	165/108
	TC	6	10750/2840
Norman	FC	8	75/48
	FS	8	106/70
	TC	5	18650/6147
Caddo Gap	FC	7	43/45
	FS	8	209/437
	TC	6	24558/12902
Glenwood	FC	8	83/151*
	FS	8	387/817
	TC	6	10200/8453
Amity	FC	8	19.28
	FS	8	52/41
	TC	6	14583/7150
Highway 84	FC	8	21/18
	FS	8	115/96
	TC	6	15133/2988

Thirteen tributaries were investigated for bacterial loading (Table 4). Fecal coliform bacteria did not exceed the EPA criterion in any samples from Beech and Huddleston Creeks, but 13% of samples from Caney Creek and South Fork Caddo River and 14% of samples from Gap, Smith and Polk Creeks exceeded EPA criteria. Excessive bacteria were also present in 25% of samples from Lick and Collier Creeks, 38% of samples from Mill and Sweetwater Creeks, 63% of samples from Mudlick Creek and 86% of samples from Rock Creek. Sweetwater and Mudlick tributaries are located above the Glenwood site in the river proper and would relate to the high counts at the river station.

Chemical and physical parameters of the Caddo River and its tributaries are generally within acceptable limits. However, there appear to be excessive bacterial loading in some tributaries and around the middle reaches of the river proper. Statistically significant changes seem to have occured since the 1970s study. However, one must exercise care in accepting such data at face value, particularly becauses of the impact of heavy rainfall runoff on such a small river system.

Table 4. Bacterial data from thriteen tributaries during 1992. EPA criterion for FC=200/100ml. *Some samples exceeded EPA criterion.

Site	Variable	No. Samples	Mean/Std Dev.
Beech	FC	8	37/41
	FS	8	157/135
	TC	6	15126/6994
Polk	FC	7	190/348*
	FS	7	1210/2428
	TC	4	29050/28049
Lick	FC	8	190/194*
	FS	8	205/125
	TC	6	17400/9014
Huddleston	FC	8	36/32
	FS	8	336/473
	TC	6	13790/9833
Collier	FC	8	162/241*
	FS	8	118/71
	TC	6	16875/5337
Mill	FC	8	504/723*
	FS	8	335/292
	TC	6	24256/14283
Smith	FC	8	158/157*
	FS	8	291/324
	TC	6	23006/15047
Gap	FC	7	102/185*
	FS	8	199/177
	TC	6	7615/3689
South Fork Caddo River	FC	8	59/78*
	FS	8	88/73
	TC	6	15325/3648
Mudlick	FC	8	1927/4214*
	FS	8	143/130
	TC	6	26566/27306
Sweetwater	FC	8	320/336*
	FS	8	458/358
	TC	6	19767/11344
Rock	FC	7	402/389*
	FS	7	265/142
	TC	5	18650/5871
Caney	FC	8	45/76*
	FS	6	377/424
	TC	6	1651/3998

Acknowledgements

We would like to thank Dr. Joe Nix, Professor of Chemistry, Ouachita Baptist University for his assistance and use of his labortory. This study was supported in part by a Henderson State University faculty research grant. Thanks are extended to Thomas House who spent many hours helping in the field.

Literature Cited

American Public Health Association. 1989. Standard methods of the examination of water and wastewater, 17th Edition. APHA, Inc. New York.

EPA. 1986. Quality Criteria for Water. Environmental Protection Agency PB-263943. Washington D.C.

Nix, J.F., R.L. Meyer, E.H. Schmitz, J.D. Bragg and **R. Brown** 1975. Collection of environmental data on DeGray Reservoir and the watershed of the Caddo River, Arkansas. U.S. Army Engineer Contract No. DACW39-75-C-0025.

Ridlehoover, Bobbi. 1992. State gets failing marks on many clean tests. Arkansas Democrat-Gazette. Feb. 9, p 22-23A.

Sokal, Robert R. and **R. James Rohlf.** 1981. Biometry. 2nd ed. W.H. Freeman and Company. 859 pp.

In Vivo Spectroscopic and Imaging Studies of Photosensitizers in Photodynamic Therapy

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Abstract

Photodynamic Therapy (PDT) has emerged as a useful cancer treatment modality which utilizes a tumor localizing dye and activating light to selectively destroy neoplastic tissue. In an effort to understand the newly synthesized photosensitizers, we are studying them in a mouse tumor model grown on the dorsal side of the foot by *in vivo* magnetic resonance techniques. We have synthesized several photosensitizers which are specifically labeled with fluorine. Several coils appropriate for the tumor study by ^{19}F NMR were designed and constructed for this project. The solenoid coil tunable to both ^{1}H and ^{19}F nuclei was used to monitor the ^{19}F labeled photosensitizer in the mouse foot tumor. An *in vivo* ^{19}F NMR technique was used to study the retention of the photosensitizer over time in the tumor. We have used ^{31}P NMR to study the outcome of PDT after using the new photosensitizer.

Introduction

Magnetic resonance spectroscopy (MRS) and magnetic resonance imaging (MRI) have significant impact on both basic research and clinical applications due to their non-invasive nature and sensitivity to molecular structure, interactions, and mobility. Additionally, MRS can be quantitative under proper conditions and MRI can provide morphological images.

Photodynamic Therapy (PDT) is an expermimental cancer treatment modality which selectively destroys cancer cells by interaction of light with a photosensitizing dye, presumably via singlet oxygen formation (Weishaupt et al., 1976). There are, however, some questions which need answers, such as 1) the time period for which photosensitizers are retained in the tumor, and 2) the optimum time at which laser irradiation can ve initiated. A non-invasive way of monitoring the photosensitizer in the tumor would be useful in PDT studies and magnetic resonance is one such useful tool.

Extensive research on photosensitizer localization in cancerous tissue has been reported (Kessel and Chou, 1983; Dougherty et al., 1984; Swincer et al., 1984). Researchers have detected the presence of photosensitizers in cells (Bottiroli et al., 1984; Moan, 1984) using their fluorescence properties. The measurements of absolute concentration of the photosensitizers *in vivo* have been attempted and have been found to be extrememly difficult because of the dependence of fluorescence efficiency on the tumor tissue, and due to the fact that the fraction of detected emitted photons depends upon the tissue type, the source, and the detector geometry.

Monitoring the effect of PDT through *in vivo* ^{31}P MRS has been used in biomedical *in vivo* sutdies, and this method has revealed alterations in energy and phospholipid metabolism before and after laser irradiation. Ceckler et al. (1986) have reported dramatic and often near complete decreases in nucleoside triphosphate (NTP) peaks accompanied by significant increase in inorganic phosphate (Pi) within four hours of PDT treatment. Completely non-invasive MR can provide a measure of the concentration of the photosensitizers and their metabolites within tumors. Detailing pharmacokinetics and drug concentrations within the tumor will help determine the minimum doses to insure the fewest side effects for humans undergoing PDT. These studies will aid in the development of a more effective protocol for humans.

In this paper we will discuss: 1) the design and fabrication of RF coils for MRS and MRI tumor studies, 2) tumor bioenergetics monitored by ^{31}P MRS, and 3) the detection of the ^{19}F labeled photosensitizers in radiation induced fibrosarcoma (RIF) tumors *in vivo*. We chose fluorine as the labeled element because the ^{19}F isotope has 100% natural abundance, a spin of 1/2, and an NMR sensitivity that

is 83% that of hydrogen. *In vivo* studies of porphyrin photosensitizers are very limited. In fact, to our knowledge, there are no known reports of *in vivo* MR studies attempting to detect such sensitizers in cancerous or non-cancerous tissue. Comprehensive knowledge of the extent of localization and the rate of accumulation is of immense value in PDT.

Materials and Methods

MRS and MRI Coils.--Figure 1A shows an air core solenoid coil with four equally spaced turns which is 1.5 cm in diameter and 2.1 cm in length. In order to tune to the resonance frequencies for both ^{1}H and ^{19}F and to insure a good circuit quality factor, Q, we mounted the copper wire on a Plexiglas (Rohm and Haas, Canada, Inc.) insulator. The fixed capacitors were 2.5 pF (Dielectric Laboratories, Inc.) In order to maximize the tuning range, we had to minimize the scattering capacitance and any connector resistance. Frequency properties were measured with a Wiltron 6400 Series RF Network Analyzer.

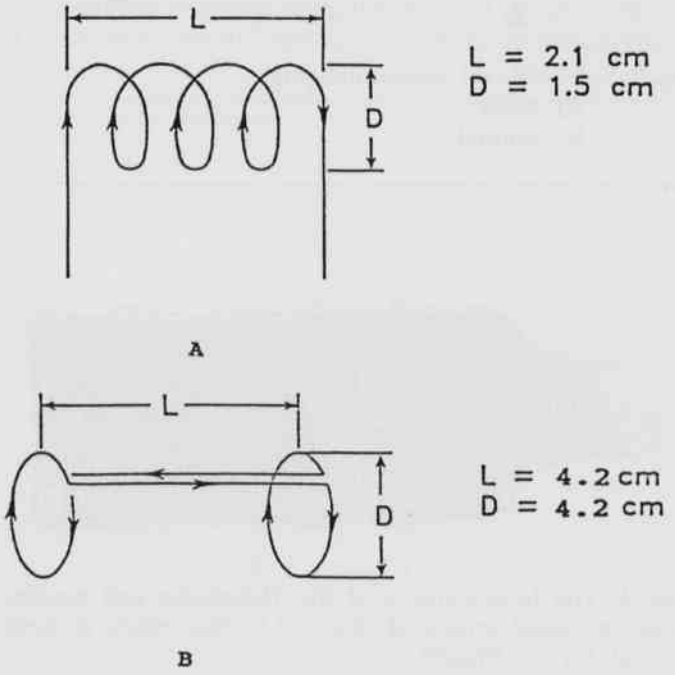

Fig. 1A. The dimensions of the solenoid coil
1B. The dimensions of the Helmholtz coil

Helmholtz Coil.--To insure a uniform imaging region for the tumor studies, the diameter and the length of the coil were optimally designed. The diameter, d, was chosen approximately equal to the length, a, (d = 4.2 cm; a = 4.2 cm), to maximize the homogeneity of the field region. Fig. 1B shows the geometric design of the Helmholtz coil. The coil was constructed by first winding a 3.30 mm wide by 0.08 mm thick adhesive backed copper foil on the cylindrical fluorine free tubing. The coil was glued to a Plexiglas plate to avoid any movement which adversely would effect the resonant frequency. All connections were short to minimize the resistance and scattering capacitance. Also, we used fluorine free capacitors and materials.

PDT on the RIF Tumor.--Fresh RIF cells were injected into the flank of male mice (C3H/HeN). After an appropriate tumor size was reached, it was cut open and a small piece of the tumor was implanted on a mouse foot. A mouse foot tumor of proper size (400-600 mm^3 for imaging and spectroscopy) was obtained after 10 to 15 days.

Several background control spectra were collected with only the coil and the coil with a typical tumor. No fluorine peaks were observed. The ^{19}F labeled photosensitizer compound was dissolved in distilled water and the spectrum was recorded in the GE 4.7T animal imager using the solenoid coil in the balanced configuration. The photosensitizer was injected IP (25 mg/kg) and after 24 hours PDT treatment was initiated wtih a laser power of 150 mW/cm^2. The total light energy was 50-100 joules at the photosensitizer absorption wavelength of 630 nm. The Ar+ CW pumped dye laser output was coupled via an optical fiber in the PDT experiment. All ^{31}P spectra were obtained on a General Electric 4.7T animal imaging system. A home-built phosphorus coil was used in acquiring spectra. Labeled ^{19}F photosensitizer was detected *in vivo* by using the home-built balanced solenoid coil.

Results and Discussion

Comparison of the Balanced and Unbalanced Coils.--The coil configuration is a very important factor in determining the frequency response of both the solenoid coil and the Helmholtz coil. Both the balanced and unbalanced configurations of the solenoid coil (as shown in Figs. 2A, 2B) were tested. The balanced coil was found to be more symmetrical about its resonant frequency compared to the unbalanced coil.

Coil Performance Tests Using Phantom.--The purpose of building coils tunable to both ^{1}H and ^{19}F nuclei was to perform proton imaging, as well as fluorine spectroscopy or imaging, using the same coil without disturbing the animal. In addition it also helps in shimming the region of

interest using the proton frequency since all biological samples have large amounts of water, whereas, the amount of naturally occurring fluorine compounds are so small, they give no background signal. Furthermore, to obtain fluorine signals from a localized region of interest, we need proton images as a reference or guide.

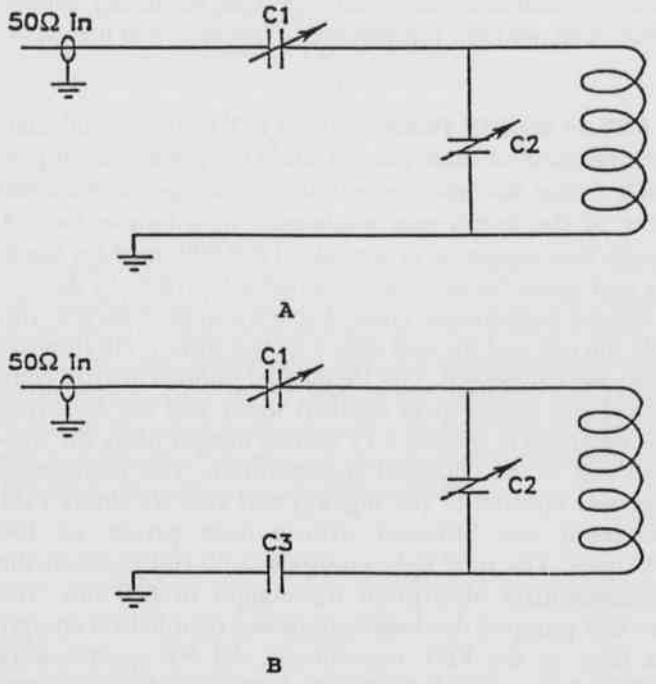

Fig. 2A. Schematic of the unbalanced coil
2 B. Schematic of the balanced coil

A phantom is an ideal sample for testing the imaging and spectroscopic properties of the doubly-tuned coil. Fig.3 shows the phantom images for the balanced solenoid coil in both the axial and sagittal directions and Fig. 4 shows the sagittal image from the Helmholtz coil. From these images, we concluded that the solenoid coil was not suitable for the imaging studies. The Helmholtz coil has a very good homogenous imaging region which is large enough for the mice foot tumor studies.

^{31}P MR Studies.--Fig. 5 shows the ^{31}P spectrum of a mouse foot tumor before the PDT. Figs. 6 and 7 show ^{31}P spectra recorded 20 min and 17 h after PDT. While small NTP peaks persist at the end of 20 min, the NTP peaks have disappeared at the end of 17 h indicating that all of the cancer cells have been killed. These results are similar to those of Ceckler et al. (1986). After three days, the RIF tumors on the mice feet stopped growing and began to shrink. After six days the tumors had disappeared totally.

Detection of ^{19}F Labeled Drugs in the Tumor.--Our preliminary studies on the ^{19}F labeled photosensitizer indicate that they can be non-invasively monitored by NMR spectroscopy. In Fig. 8 we show the first labeled photosensitizer peak five hours after direct injection of the labeled compound. This method of detecting and monitoring the photosensitizer is the first of its kind and this technique holds much promise for PDT research.

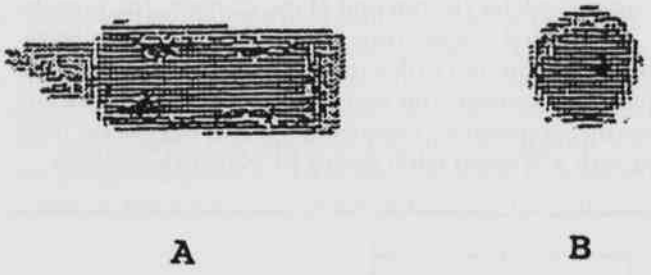

Fig. 3. Solenoid coil proton imaging
A). Axial
B). Sagittal

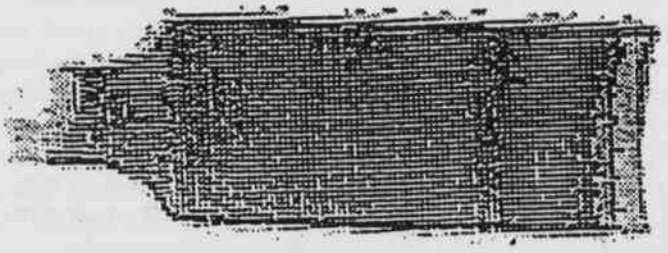

Fig. 4. The homogeneity of the Helmholtz coil proton imaging. Total length is about 1.5 cm, which is long enough for our project.

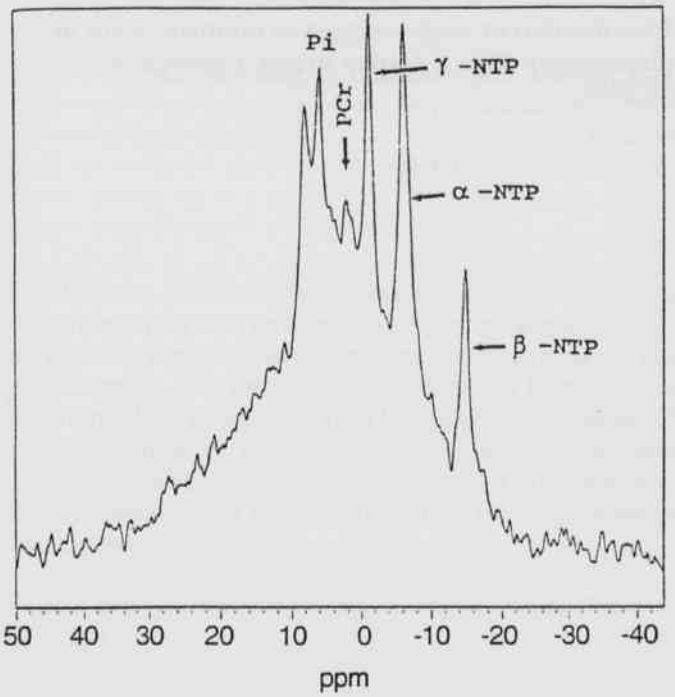

Fig. 5. ^{31}P-NMR spectrum of RIF tumor 24 hrs after the injection of 25 mg/kg of a photosensitizer, prior to PDT. Spectrum was obtained using 900 scans, a 90° pulse of 13 us, repetition time of 1 sec, and a total accumulation time 15 min.

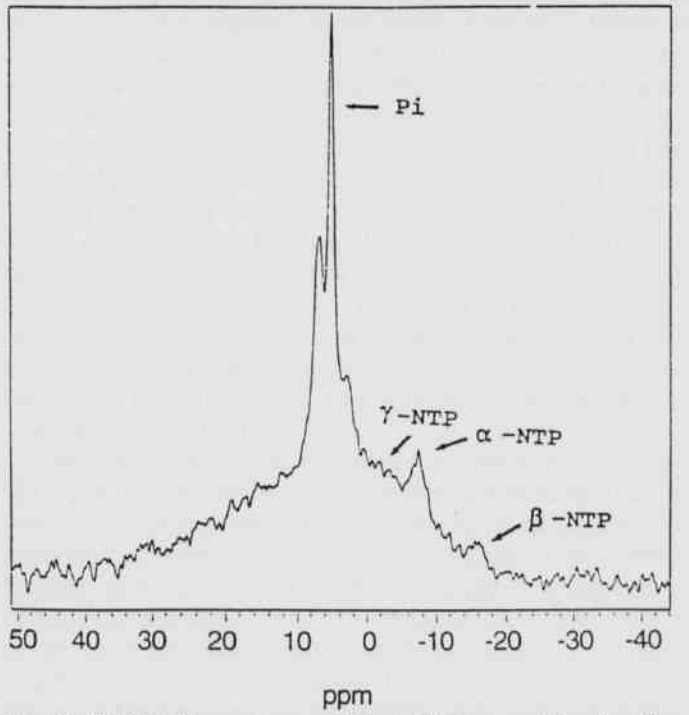

Fig. 6. ^{31}P-NMR spectrum of the RIF tumor 20 min after PDT, under same experimental conditions as prior to PDT.

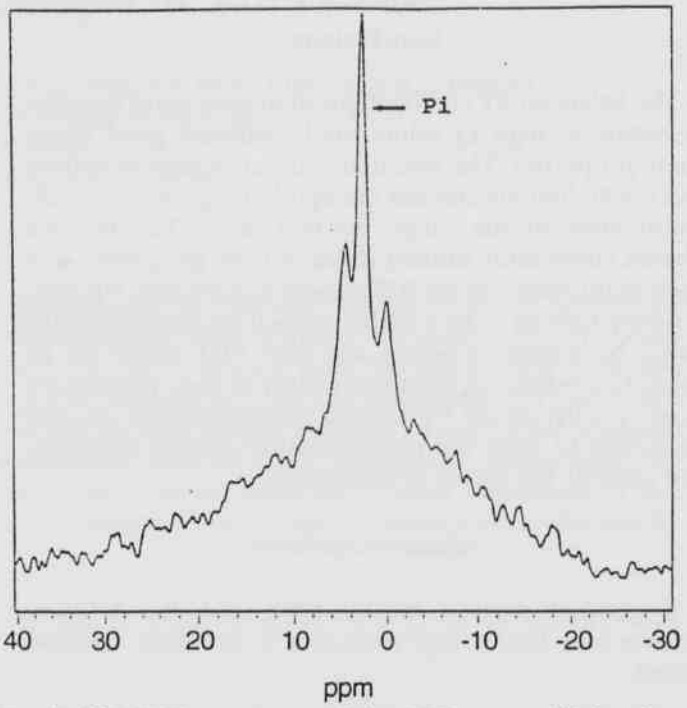

Fig. 7. ^{31}P-NMR spectrum of the RIF tumor 17 hr after PDT under same experimental conditions as prior to PDT.

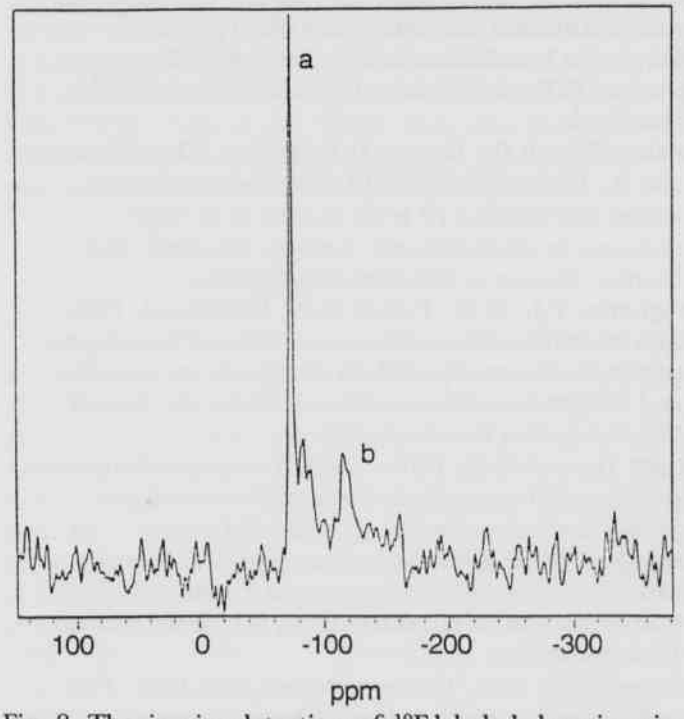

Fig. 8. The *in vivo* detection of ^{19}F-labeled drug in mice RIF tumor five hrs after injection. The parameters were: data size 8k, 7200 accumulations, repetition time 300 ms, a 10 μs 90° pulse, ^{19}F transmitter center at 188.26 MHz, total accumulation time of 36 min.

Conclusions

The balanced RF coil configuration gave good frequency response, high Q values, and exhibited good linear phase properties. The solenoid coil has enough sensitivity and the Helmholtz coil has enough homogeneity to study tumor sizes in the range 300-600 mm.[3] The fluorine labeled compound studied displayed the properties of a good photosensitizer on RIF tumors in mice feet. ^{31}p spectroscopy appears to be a useful method for monitoring the tumor bioenergetics before and after PDT which can be helpful in evaluating photosensitizers *in vivo*. Preliminary *in vivo* results on the ^{19}F labeled photosensitizers are very promising to study the photosensitizer uptake, retention, and possibly the extent of localization.

Acknowledgements

A grant in support of this work from the Arkansas Science and Technology Authority is gratefully acknowledged.

Literature Cited

Bottiroli, G., F., Doccio, I., Frietas, R., Ramaponi, and **C.A., Sacchi.** 1984. Hematoporphyrin derivative: fluorometric studies in solution and cell. Pp. 125, *In* Porphyrin Localization and Treatment of Tumor (Doirin, D.R., and Gomer, C.J., eds.) Plenum Press, New York.

Ceckler, T.L., R.G., Bryant, D.P., Penny, S.L., Gibson, and **R., Hilf.** 1986. ^{31}P-NMR Spectroscopy demonstrates decreased ATP levels *in vivo* as an early response to photodynamic therapy, Biochem, and Biophy. Commun. Vol. 140, No. 1 273 pp.

Dougherty, T.J., W.R., Potter, K.R., Weishaupt. 1984. The structure of the active component of hematoporphyrin derivative. Pp. 301, *In* Porphyrin Localization and Treatment of Tumor (Doirin, D.R., and Gomer, C.J., Eds.) Alan R. Liss, New York.

Kessel, D., and **T.C., Chou.** 1983. Tumor-localizing components of the porphyrin preparation hematopor phyrin derivative. Cancer Res. 43:1994.

Moan, J. 1984. Fluorescence of porphyrin in cells. Pp. 125, *In* Porphyrin Localization and Treatment of Tumor (Doirin, D.R., and Gomer, C.J., Eds.) Plenum Press, New York.

Swincer, A.G., V.C., Trenerry, Ward, A.D. 1984. The analysis and some chemistry of hematoporphyrin derivative. Pp. 285, *In* Porphyrin Localization and Treatment of Tumor (Doirin, D.R., and Gomer, C.J. Eds.) Alan R. Liss, New York.

Weishaupt, K.R., C.J., Gomer, T.J., Dougherty. 1976. Identification of singlet oxygen as cytotoxic agent in photoactivation of a murine tumor. Cancer Res. 36:2326.

Stress Induced Protein Changes in Tall Fescue

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Abstract

Tall fescue (*Festuca arundinacea* Schreb.), the most important pasture grass in Arkansas, exhibits different agricultural properties when it is infected by its mutualistic endophyte *Acremonium coenophialum* Morgan-Jones and Gams. We postulate that the presence of endophyte exerts a stress on the host that enhances or detracts from the host's ability to express specific genes. We tested this hypothesis by heat stressing infected and non-infected, juvenile and mature tall fescue, and examining their protein profiles by SDS-PAGE analysis. The results indicate that mature, infected, stressed grass produced greater amounts of Rubisco (ribulose bisphosphate carboxylase-oxygenase) than all other treatments. Additionally, the mature, infected, stressed grass exhibited a 20 kDalton protein band which was not apparent in other treatments. These observations support the possibility that the endophyte prestresses the grass, and they suggest a molecular mechanism for this response.

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Introduction

Tall fescue (*Festuca arundinacea* Schreb.) is an important and well-adapted forage and turf grass in Arkansas, as well as in many other regions of the world. Certain cultivars of this species are known to harbor the mutualistic endophyte *Acremonium coenophialum* Morgan-Jones and Gams. The association seems to contribute many selective advantages to the host plant including resistance to insect herbivory (Patterson et al., 1991), disease (Gwinn and Gavin, 1992), nematodes (West et al., 1989) increased photosynthetic output (Clay, 1990) and an increased tolerance to drought (West et al., 1993) and heat (Clay, 1990). Unfortunately, toxic alkaloids produced by the fungus promote the conditions known as "ryegrass staggers" and "fescue toxicosis" in grazing animals, conditions that cause an estimated annual loss of $50 million (1989 figures) in Arkansas alone (Daniels, 1989).

Insect and nematode resistance in endophyte-infected (E+) plants has been fairly well-characterized (Latch, 1993). Proposals have been made to account for the observed increase in photosynthetic output (Clay, 1990). Studies that have been made to suggest mechanisms responsible for the observed increase in the stress survival of E+ over non-infected (E-) grasses suggest a possible combination of morphological traits present in infected grasses (Arachavaleta et al., 1989) with induced differences in carbohydrate metabolism (Richardson et al., 1992, 1993). It is our hypothesis that the presence of the endophyte in tall fescue induces a mild "pre-stress" on the plant, mobilizing the plant's endogenous defense systems that better enable it to survive greater stresses induced by drought or heat. To test this idea, we made preliminary studies examining differences in the SDS-PAGE electrophoresis of the total proteins of an E+ (cultivar "Kentucky-31") and E- variety (cultivar "Fawn") before and after a severe heat stress. These tests were further subdivided to examine differences between juvenile (<60 days post germination) and mature (>6 mon) grasses.

Materials and Methods

Six 36 cm x 26 cm plots each of E+ and E- tall fescue were seeded using seed samples obtained from the Arkansas Plant Board. E+ samples were *F. arundinacea* Schreb. var. *genuina* cultivar "Kentucky-31" and E- samples were of the cultivar "Fawn" (same variety). The samples were Plant Board certified at 99% and 0% *Acremonium coenophialum* infection, respectively. Both cultivars used were hexaploids (2n = 42). Infection was recertified using protocol outlined by the Association of Official Seed Analysts. The plots were randomized and maintained for 8 months (June 1992 - March 1993) in a greenhouse. Seedings were thinned to the strongest plants every three days from 2 weeks to 4 weeks post-germination. Plots were fertilized once monthly with 50-30-15 fertilizer (Super K-Gro). Of these randomized plots, mature samples were selected by choosing one each of the healthiest plots for analysis. The chosen plots were moved to a controlled environmental

chamber (Baxter Scientific Products Cryo-Fridge) at 24°C and 12 h/day light exposure for one week prior to removing 5 g leaf tissue for pre-stress analysis. Juvenile samples were grown from germination in the chamber and were sampled at the 30 day post-germination mark for pre-stress analysis (juvenile and mature plants were sampled simultaneously), removing only 1-2 g of tissue due to lowered availability. The plots were then subjected to heat stress (42° for 48 h with 12 h/day light) and were then sampled post-stress. No readjustment period was allowed between stress and plant harvest.

Protein was extracted immediately after harvest by first freezing the sample tissue with liquid nitrogen and grinding with porcelain mortar and pestle. The ground tissue was homogenized into 1.5x volume extraction buffer (modified from Mehta et al., 1991, leupeptin excluded). The homogenate was strained through Miracloth and was centrifuged at 12,000 x g for 20 min to remove cell debris. Total proteins were then separated by SDS-PAGE in both 12% and in 10-12% continuous gradient gels (Sambrook et al., 1989). Proteins were stained with Coomassie Blue and lanes were analyzed for band differences on a Molecular Dynamics Model 300A laser densitometer and analyzed using ImageQuant Analysis Program (Molecular Dynamics). Adjustment for protein concentration between extractions was made by equalizing the lowest density pixels between the lanes of the imaged gels.

Results

In general, each preparation yielded many distinct bands on the SDS-PAGE gels. Although the bands were more easily visualized in the mature tissues, they were apparent to the laser scanner in the juvenile preparations as well. The Rubisco (ribulose bisphosphate carboxylase-oxygenase) large subunit band was clearly visible in all preparations and was migrating at the expected distance for its 53 kDa weight. When considering the juvenile samples only, we found no differences between any treatment or between any samples for any protein band (Fig. 1).

By using the band quantification mode of the ImageQuant Analysis Program, we found five distinct and significant protein peaks in the mature stressed E+ sample, while only four peaks were found in either mature stressed E- or mature non-stressed E+ samples (Table 1). Although the high molecular weight peaks may represent different proteins (peaks 1; Table 1), the discovery of a unique peak in the stressed grass is of current interest. When compared to either mature stressed E- or the mature non-stressed E+ samples, the additional peak was in the 20 kDa range of molecular weights, weight range being determined by migration of known molecular weight markers. Curiously, each of the other four peaks was apparent in the mature stressed E- and mature non-stressed E+ samples with the only difference in magnitude being the Rubisco.

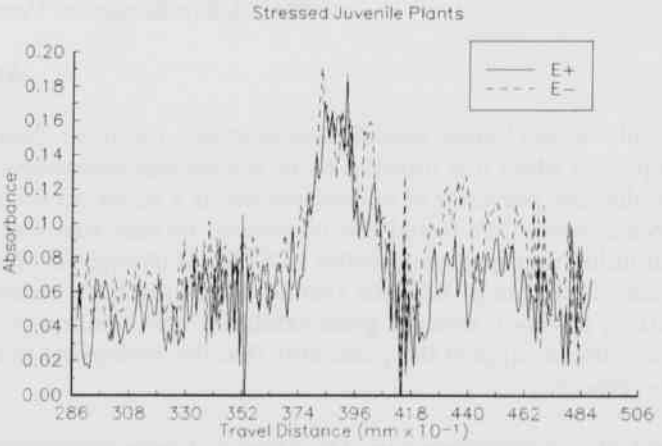

Fig. 1. Profiles of electrophoretic separations of proteins from stressed juvenile E+ and E- plants. The rubisco peak is centered at approximately 380 x 10^{-1} mm.

Table 1. Quantified peaks in stressed mature E+ and E- plants. Peak numbers refer to approximately corresponding peaks in E+ and E- plants.

Infection status	Peak	Peak Y-position
E+	1	156
	2	391
	3	454
	4	516*
	5	716
E-	1	251
	2	396
	3	434
	5	781

*lacks corresponding peak in E- scan

Because Coomassie Blue stains different proteins to differing extents, quantitative determinations of proteins without standard curves for the protein in question are not valid. However, comparisions of relative amounts between bands of the same protein (particularly those on a single gel) are allowable, as are, to a lesser extent, comparisons between different proteins on the same gel (Hames, 1990). Given this proviso, Rubisco was evident in

what appeared to be a higher concentration than other proteins. We observed approximately a 5-fold increase in the Rubisco band intensity in the mature stressed E+ samples as compared to all other mature samples (Fig. 2). The magnitude of this protein was approximately the same (about 6% of total protein) in mature stressed E- and mature non-stressed E+ samples.

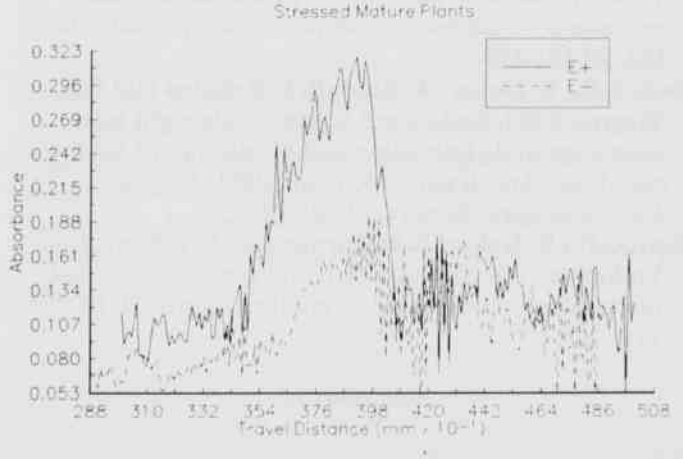

Fig. 2. Profiles of electrophoretic separations of proteins from stressed mature E+ and E- plants. The difference in peak absorbance at 380 x 10^{-1} mm reflects a five-fold increase of Rubisco in the stressed E+ sample.

Discussion

Our working hypothesis involves the notion that the endophyte induces some type of stress related response in the grass host. Futhermore, because other studies have demonstrated increased drought tolerance, greater growth, and osmotic differences (Clay, 1990) between E+ and E- plants, our hypothesis suggests that specific protein synthesis pathways are being regulated differentially. If that is the case, SDS-PAGE analysis should detect specific protein differences between infected and non-infected grass. In the presence of an environmental stress, that effect should be magnified and more easily observed.

The preliminary observations presented in this work support the "pre-stress" hypothesis; however, they do not eliminate alternative hypotheses. Specifically, we observed no protein differences among juvenile samples regardless of treatment (Fig.1). Because we and others (Welty et al., 1986) have not been able to reliably observe fungal hyphae in leaves younger than 30 days, we suspect that the influence of the endophyte is non-existent. Our observation of no protein differences among juvenile tissues subjected to either stress or infection agrees well with the observed life cycle of the endophyte and the above prediction.

When we considered the mature tissue, we made two major classes of observations. First, we observed a unique protein peak in the stressed E+ tissue. The approximate molecular weight (20 kDaltons) of this peak coincides well with a known superfamily of low molecular weight heat shock proteins (LMW HSP's) in plants, ranging in weight from 17 kDa to 27 kDa. These proteins are present in negligible amount in unstressed tissue, but can be some of the most abundant proteins present in heat stressed tissue (Vierling, 1991). The fact that eukaryotes other than plants possess far fewer of these LMW HSP's eliminates the possibility of the band difference being directly attributable to the presence of the endophyte and indicates that it is most likely the product of the infected plant itself. While the absence of the band in unstressed E+ seems to preclude the "pre-stress" hypothesis, it should be noted that these proteins, if indeed the band is a member of this family, seem to be largely heat regulated (Vierling, 1991). The fact that E+ plants were able to mobilize production of this HSP would support the "pre-stress" hypothesis, but as this protein difference has not yet been characterized, this would not preclude other hypotheses.

Finally, we observed that the stressed E+ tissue produced more Rubisco than either the stressed E- or non-stressed E+ material. As Rubisco is the primary enzyme system involved in photosynthesis, this would be consistent with enhanced photosynthetic rates and osmotic balance previously observed in E+ material (Clay,1990). Also, as the apparent levels of Rubisco were similar in stressed E- and non-stressed E+ (both slightly greater than in non-stressed E-), this suggests that E+ is normally producing this protein at a similar rate as stressed E- tissue.

In conclusion, we have preliminary evidence from three sources to suggest that the presence of endophyte in tall fescue induces some type(s) of pre-stress condition(s) in the plant. First, we only observed an effect in mature plants. As the endophyte can not be detected until after 30 days post-germination, this observation supports the hypothesis. Second, an additional protein peak in the 20 kDalton molecular weight range was observed in stressed E+ grass. These proteins are in the molecular weight range of known heat shock proteins particular to plants, providing a possible molecular mechanism for the enhanced heat and drought resistance observed in E+ tall fescue. Finally, preliminary evidence suggests that stressed E+ material produced quantitatively more Rubisco than either stressed E- or non-stressed E+ tissue, while stressed E- and non-stressed E+ tissue produced similar amounts; either of which is more than non-stressed E- material. As these results are preliminary, additional research involving other genotypes must be conducted.

Additionally, other stress responses must be eliminated to ascertain that we are observing a "pre-stress" induced by endophyte.

Acknowledgements

We wish to thank the Arkansas Plant Board for providing the seed samples used in this experiment and the Arkansas Native Plant Board for providing additional funding. We wish to also acknowledge the help of Virginia Johnson at McClellan Veterans Hospital for aid with the laser densitometer and Dr. Jim Peck (UALR) for his invaluable proof-reading services.

Literature Cited

Arachevaleta, M., C.W. Bacon, C.S. Hoveland and **D.E. Radcliffe.** 1989. Effect of tall fescue endophyte on plant response to environmental stress. Agron J. 81:83-90.

Clay, Keith. 1990. Fungal endophytes of grasses. Ann. Rev. Ecol. Syst. 21:275-297.

Daniels, L.B. 1989. Historical perspective of fescue toxicosis in Arkansas. Proc. Ark. fescue toxicosis conference 1989. Ark. Agri. Exp. Stat. Spec. Report. 140:1-6.

Gwinn, K.D. and **A.M. Gavin.** 1992. Relationship between endophyte infestation level of tall fescue seed lots and *Rhizoctonia zeae* seeding disease. Plant Dis. 76:911-914.

Hames, B.D. and **D. Rickwood.** 1990. Gel electrophoresis of proteins: a practical approach. Oxford University Press.

Latch, G.C.M. 1993. Physiological interactions of endophytic fungi and their hosts. Biotic stress tolerance imparted to grasses by endophytes. Agric. Ecosystems Environ. 44:143-156.

Mehta, R.A., B.L. Parsons, A.M. Mehta, H.L. Nakhasi and **A.K. Mattoo.** 1991. Differential protein metabolism and gene expression in tomato fruit during wounding stress. Plant Cell Physiol. 32:1057-1065.

Patterson, C.G., D.A. Potter, and **F.F. Fannin.** 1991. Feeding deterrency of alkaloids from endophyte-infected grassed to Japanese beetle grubs. Entomol. exp. appl. 61:285-289.

Richardson, M.D., G.W. Chapman Jr., C.S. Hoveland and **C.W. Bacon.** 1992. Sugar alcohols in endophyte-infected tall fescue under drought. Crop Sci. 32:1060-1061

Richardson, M.D., C.S. Hoveland and **C.W. Bacon.** 1993. Photosynthesis and stomatal conductance of symbiotic and nonsymbiotic tall fescue. Crop Sci. 33:145-149

Sambrook, J., E.F. Fritsch and **T. Maniatis.** 1989. Molecular cloning: a laboratory manual, second edition. Cold Spring Habor Lab. Press.

Vierling, E. 1991. The roles of heat shock proteins in plants. Annu. Rev. Plant Physiology Plant Mol. Biol. 42:579-620.

Welty, R.E., M. Azevedo and **K.L. Cook.** 1986. Detecting viable *Acremonium* endophytes in leaf sheaths and meristems of tall fescue and perennial ryegrass. Plant Dis. 70:431-435.

West, C.P., E. Izekor, A. Elmi, R.T. Robbins and **K.E. Turner.** 1989. Endophyte effects on drought tolerance, nematode infestation and persistence of tall fescue. Proc. Ark. fescue tox. conf. 1989. Ark. Agric. Exp. Stat. Spec. Report. 140:23-27.

West, C.P., E. Izekor, K.E. Turner and **A.A. Elmi.** 1993. Endophyte effects on growth and persistance of tall fescur along a water-supply gradient. Agron. J. 85:264-270.

Ultraviolet Spectra of Acetic Acid, Glycine, and Glyphosate

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Abstract

The influence of pH on the ultraviolet spectra of 0.001, 0.005, and 0.010 M glyphosate, glycine, and acetic acid was investigated. Each dilution of each acid was adjusted to acidic, neutral, and basic pH values. Ultraviolet spectra were recorded from 300 to 200 nm for each acid-dilution-pH combination. The wavelength of maximum absorption (λ_{max}) of glyphosate and glycine was slightly higher in the high pH solutions than in the neutral and low pH solutions. The λ_{max} of acetic acid was apparently unaffected by changes in pH. Molar extinction coefficients (ε) at λ_{max} increased with pH for all three acids. Regression analysis of the absorbance versus concentration for each acid-pH combination indicated linear relationships. Coefficients of determination (r^2) were greater than 0.88 at both 210 and 215 nm for all acids and pH values.

Introduction

Ultraviolet (UV) spectroscopy of organic compounds usually indicates little about structural characteristics. Organic compounds that contain certain functional groups such as carboxyls, carboxylates, aldehydes, ketones, and esters have UV absorption maxima in the range of 190 to 210 nm. UV spectra of these moieties are not as diagnostic as infrared spectra, but may be used in quantifying the chromophore bearing species (Willard, et al., 1974). The mechanism of UV radiation absorption of these single chromophores is the excitation of p-orbital non-bonding electrons to antibonding σ-orbitals as well as $\pi \rightarrow \pi^*$ of the carboxylate carbon. The transitions are $n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$, and occur on the carbon-oxygen unsaturated bonds (Parikh, 1974; Scott, 1964).

Glyphosate, or N-phosphonomethyl glycine, (Fig. 1), is an organic acid and the active ingredient in the herbicide Roundup^R marketed by the Monsanto Chemical Corporation. The rapid adsorption of glyphosate by soils and soil compounds has made the compound the focus of many studies (Hance, 1976; Sprankel et al., 1975; Torstensson and Amisep, 1977). Generally, these studies have shown glyphosate to be strongly adsorbed by soils and soil constituents under a variety of conditions. Certain studies have been conducted to examine the UV spectra of solution-phase, glyphosate-metal complexes and have failed to show the contribution of the uncomplexed carboxyl and carboxylate groups of glyphosate (Glass, 1984; Glass, 1987; McBride and Kung, 1989). The UV absorption of the acid functionality has been used in the analytical determination of glyphosate thereby demonstrating its importance (Burns, 1983; McConnell and Hossner, 1985; Errata, 1991).

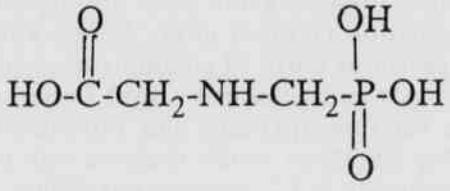

Fig. 1. Glyphosate

The objective of this research was to examine the UV spectra of glyphosate and two other carboxylic acids, and determine the wavelength of maximum absorbance (λ_{max}) and the molar extinction coefficients (ε) at λ_{max}, 215 nm, and 210 nm as influenced by pH. Further, regression analysis was used to determine the linearity of graphs of UV absorbance at 210 and 215 nm versus acid concentration.

Materials and Methods

Organic Acids.---Glyphosate (99%) was obtained from the Monsanto Chemical Corporation and used without further purification. Reagent grade glycine and acetic acid where purchased from Fischer Scientific Supply of Plano, Texas and also used without further purification. Dilutions of acetic acid were quantified with titrametric

techniques with standard base. Samples of the acids were then diluted to 0.010, 0.005, and 0.001 M. Each sample was adjusted to pH values near 3, 7, and 10 with NaOH.

Instrumentation.--The ultraviolet spectra of the protonated and deprotonated acids at the three concentrations were recorded from 300 to 200 nm on a Perkin-Elmer Model 25 UV-visible spectrophotometer. Matched silica-quartz cuvettes with a 1.0 cm path length from Perkin-Elmer (Lot Number 14993) were used to contain the diluted acids. Scan speed was set at 20 nm/min. and 1.0 nm/in. The spectra of the 0.010 M solutions were used to determine the λ_{max}, the absorbance maxima, and the ε at λ_{max}.

The absorbances and ε of the samples were also recorded at 210 and 215 nm, and analyzed using linear regression. Regression analysis gave estimates of slopes and intercepts, and the linearity of the relationship between absorbance and concentration for each acid and pH.

Results and Discussion

Spectra of all three compounds at the three concentrations and pH values indicate UV absorbance from approximately 220 to below 200 nm. This is the approximate wavelength range organic acids are expected to absorb UV radiation (Willard et al., 1974). The total absorbance spectra of 0.010 M solutions of glyphosate increased with pH and exhibited a shift in absorption maxima from <200 nm (pH 2.83 and 7.01) to 214 nm (pH 10.01) (Fig. 2). These results disagree with reports that state glyphosate is UV transparent (Glass, 1984; Glass, 1987).

The λ_{max} for the low and neutral pH solutions of 0.010 M glyphosate and glycine was found to be near or below 200 nm. As the pH was increased, the λ_{max} of glyphosate and glycine increased to 214 and 210 nm, respectively. The acetic acid solutions exhibited λ_{max} at 204, 200 and 204 nm for the low, neutral and high pH solutions, respectively (Table 1). The trend of increasing pH and increasing λ_{max} that was evident in the spectra of glyphosate and glycine was not observed with acetic acid because of its monoprotic structure. Amino acids and diacids differ from monoprotic acids in that they generally show an increase in absorbance and a shift to longer wavelengths (bathochromic shift) with increasing pH (Greenstein and Winitz, 1961; Parikh, 1974). The increase in absorbance and the bathochromic shift are attributed to the auxochrome created by dianionic structures. The λ_{max} of monoprotic acetic acid remained relatively constant with increasing pH due to absence of any auxochromes.

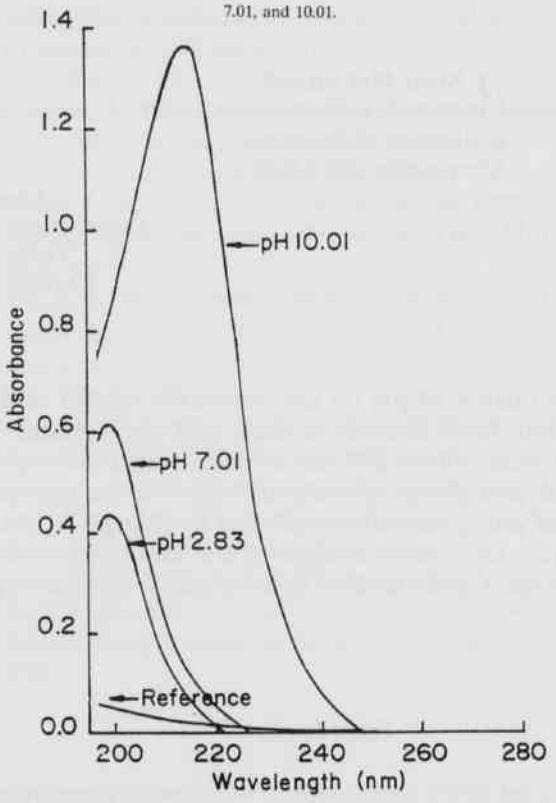

Fig. 2. Absorbance spectra of 0.010 M glyphosate solutions adjusted to pH 2.83, 7.01, and 10.01.

Table 1. Wavelength of maximum absorption (λ_{max}), maximum absorbance (A_{max}), and molar extinction coefficient (ε_{max}) of ultraviolet spectra of 0.010 M solutions of glyphosate, glycine, and acetic acid at low, neutral, and high pH values.

	Glyphosate			Glycine pH			Acetic Acid		
	2.83	7.01	10.01	3.03	6.99	9.97	3.49	6.94	10.13
λ_{max}	<200	<200	214	<200	201	210	204	200	204
A_{max}	0.430	0.615	1.37	0.510	0.650	1.16	0.325	0.670	0.885
ε_{max}	43	62	137	51	65	116	33	67	89

The ε at the λ_{max} (ε_{max}) for all three acids was found to range between 33 and 137, and increase with increasing pH (Table 1). Three groups of similar ε_{max} are apparent, and related to the solution pH. The low pH solutions of glyphosate, glycine and acetic acid had similar ε_{max} that

ranged from 33 to 51. All three ε_{max} were found to increase slightly, ranging from 62 to 67, as the pH was raised from acid to neutral. Increasing the pH of the solutions to near 10 resulted in large increases in ε_{max} with increasing pH, up to 89, was found with the acetic acid solutions. The large increases in the ε_{max} values of the glyphosate and glycine solutions indicate that the additional lone pairs of electrons present in the phosphoamide of glyphosate and the amino group of glycine act as an auxochrome causing both a bathochromic shift and an increase in absorbance. The degree of protonation of these auxochrome groups generally affects the availability of the lone pairs of electrons for $n \rightarrow \pi^*$ transitions (Parikuh, 1974). These experimental results demonstrate that the degree of protonation is a major determinant of the UV absorption characteristics of glyphosate, glycine and acetic acid.

Regression analysis of the concentrations of the individual acids and their UV absorptions indicated a high degree of linearity at 210 and 215 nm for the three pH values tested (Fig. 3). The r^2 exceeded 0.9 in all regression lines at 215 nm, and in all but one at 210 nm. The high degree of linearity indicates that these wavelengths may be used for analytical determinations of glyphosate, glycine, or acetic acid in aqueous solutions. The presence of other carboxylic acids or mixtures of these three would probably interfere in this type analysis unless a suitable separations technique were employed.

The mean of the slopes of the regression lines (215 nm) for low and neutral pH solutions of glyphosate and glycine, and all three acetic acid solutions was 18.20 with a standard deviation of ± 3.07. The range of the slopes for these solutions was from 13.59 to 23.39, thereby indicating little difference in the slopes of these regression lines. Solutions of high pH glycine and glyphosate had much higher slopes than their lower pH analogs or the acetic acid solutions. This corresponds with the increases in ε_{max} and changes in λ_{max} observed in the UV spectra of the high pH glyphosate and glycine solutions. The increased absorbance of the high pH glycine and glyphosate solutions increased the slope of the regression line.

Conclusions

Solutions of glyphosate, glycine, and acetic acid were shown to absorb ultrviolet radiation from 220 to 200 nm. Wavelength of maximum absorption and ε_{max} for glyphosate and glycine were similar at low and neutral pH. Increased pH resulted in increased λ_{max} and ε_{max}. The λ_{max} of the acetic acid solutions was seemingly unaffected by pH, while the ε_{max} was less affected by pH than the other acids.

Regression analysis of the concentrations of the acids and their UV absorbances indicates a linear relationship

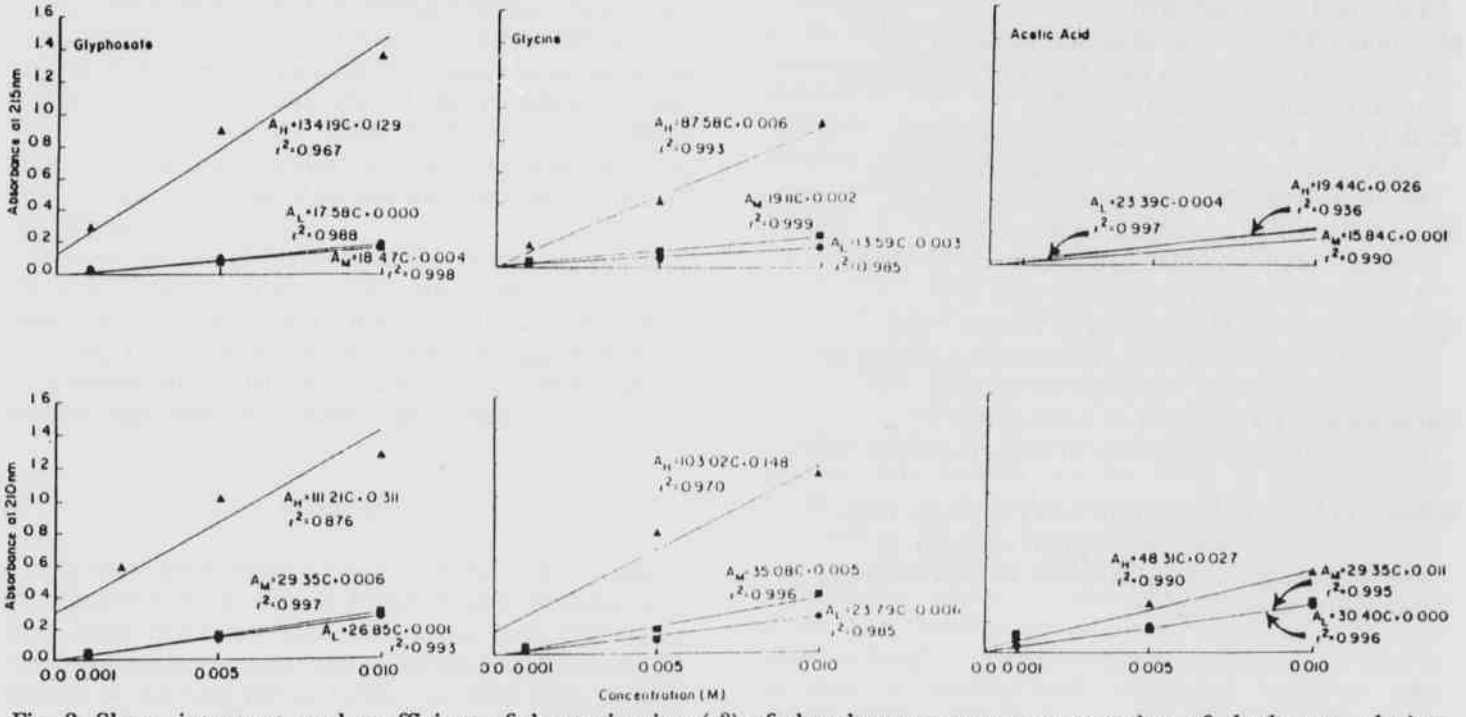

Fig. 3. Slope, intercept, and coefficient of determination (r^2) of absorbance versus concentration of glyphosate, glycine, and acetic acid at high pH (A_H), moderate pH (A_M), and low pH (A_L) values.

Journal of the Arkansas Academy of Science, Vol. 47 [1993], Art. 1

at 210 and 215 nm. The slopes of the regression lines were found to be similar for low and neutral pH solutions of glyphosate and glycine, and for all acetic acid solutions. Much higher slopes were found for high pH solutions of glyphosate and glycine. The linear relationship between concentration and UV absorbance of glyphosate provides a useful analytical method for the determination of glyphosate, and similar acids, in aqueous solutions.

Literature Cited

Burns, A.J. 1983. Liquid Chromatographic Determination of glyphosate Technical and Its Formulation: Collaborative Study. J. Assoc. Off. Anal. Chem. 66:1214-1219.

Errata. 1991. J. Agric. Food Chem. 39: 824.

Glass, R.L. 1984. Metal Complex Formation by Glyphosate. J. Agric. Food Chem. 32:1249-1253.

Glass, R.L. 1987. Adsorption of Glyphosate by Soils and Clay Minerals. J. Agric. Food Chem. 35: 497-500.

Greenstein, J.P. and **M. Winitz.** 1961. Chemistry of the Amino Acids, Volume 2. p. 1689. Robert E. Krieger Publishing Co.: Malabar, FL.

Hance, R.J. 1976. Adsorption of Glyphosate by Soils. Pesticide Sci. 7: 363-366.

McBride, M. and **K.H. Kung.** 1989. Complexation of glyphosate and related ligands with iron (III). Soil Sci. Soc. Am. J. 53: 1668-1673.

McConnell, J.S. and **L.R. Hossner.** 1985. pH Dependent Adsorption Isotherms of Glyphosate. J. Agric. Food Chem. 33: 1075-1078.

Parikh, V.M. 1974. "Ultraviolet Spectroscopy. *In* Absorption Spectroscopy of Organic Molecules. Addison-Wesley Publishing Co.: Reading, MA.

Scott, A.I. 1964. Single Chromophores. *In* Interpretation of the Ultraviolet Spectra of Natural Products. Pergamon Press, New York, NY.

Sprankel, P., W.F. Meggitt and **D. Penner.** 1975. Adsorption, Mobility, and Microbial Degradation of Glyphosate by Soils. Weed Sci. 23: 229-234.

Torstensson, N.T.L. and **A.A. Amisep.** 1977. Detoxification of Glyphosate in Soils. Weed Res. 17: 209-212.

Willard, H.H., L.L. Merritt, Jr. and **J.A. Dean.** 1974. Ultraviolet and Visible Absorption Methods. *In* Instrumental Methods of Analysis. D. Van Nostrand Company: New York, NY.

Unhatched Eggs in Nests of Red-cockaded Woodpeckers

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Abstract

During 1991 and 1992, nests of Red-cockaded Woodpeckers (*Picoides borealis*) were monitored in the Ouachita National Forest in Scott and Polk counties of west-central Arkansas. Nests in three additional woodpecker areas in Arkansas and Oklahoma were also monitored in 1992. Of 92 eggs laid in 27 nesting attempts in the Ouachita National Forest, 18 (19%) failed to hatch. When viewed in the cavities, six unhatched eggs were noticeably below average in size for the species and eight were average size. Seven unhatched eggs were removed in 1992 from seven nests in Arkansas and Oklahoma; three eggs showed some embryological development and three showed no development. Techniques used to remove unhatched eggs and results of analysis of eggs are presented. Possible management applications of egg data are discussed.

Introduction

Remnant populations of endangered Red-cockaded Woodpeckers (*Picoides borealis*) occur in several areas in Arkansas (James and Neal, 1986; 1989), at one location in southeastern Oklahoma (Masters et al. 1989), and elsewhere in the southeastern United States (Ligon et al., 1986). These cooperatively-breeding birds have been studied in the Ouachita National Forest (Ouachita NF) in west-central Arkansas as part of a management program designed to stablize and rebuild the population (Neal, 1992; Montague et al., 1993; Withgott et al., 1993). Embryological data, including egg sizes and hatching rates, could prove useful in planning recovery efforts in the Ouachita NF.

The average size of Red-cockaded Woodpecker eggs was 24.04 by 17.86 mm (Bent, 1939), but unusually large and small eggs are also laid (Ramey and Jackson, 1979; Koening, 1980). An analysis of unhatched eggs from nests in Arkansas and Oklahoma based on a new technique to remove eggs from cavity nests is presented.

Study Area

Shortleaf pine (*Pinus echinata*) forests in the Ouachita NF inhabited by groups of Red-cockaded Woodpeckers have been previously described (Neal and Montague, 1991) as have techniques used in the study of the breeding biology of the bird (Neal, 1992). In 1992 nests of Red-cockaded Woodpeckers were examined in the Ouachita NF (Scott and Polk counties, Arkansas), at Crossett Experimental Forest (Ashley County, Arkansas), Pine City Natural Area (Monroe County, Arkansas) and McCurtain County Wilderness Area (McCurtain County, Oklahoma).

Methods

During the 1991 and 1992 breeding seasons, nest trees in the Ouachita NF were climbed with ladders and nest contents examined using a light and mirror. Nests were checked at least 1-2 times each week from mid-April to early July. Clutch size, hatching rates, nestling survival, and fledging rates were determined. Nestlings were removed from cavities and banded. In 1992 nestlings were also banded at Crossett Experimental Forest, Pine City Natural Area and in McCurtain County Wilderness Area.

A battery-powered portable vacuum (e.g., Black & Decker Power Pro, DB6000 with the AK10 accessory kit) equipped with a 75-mm-long flexible hose (e.g., Hoover Elite upright vacuum hose) was used in 1992 to remove unhatched eggs from nest cavities (Fig. 1). When it was determined that an egg was not going to hatch, the flexible hose was inserted into the cavity. A nylon stocking pouch covering the end of the hose was brought into close proximity to the egg. Suction from the vacuum "cradled" the egg, permitting its safe removal from the nest cavity.

Unhatched eggs were removed from 6 to 17 May 1992 at the time nestlings were banded (usually age 7-10 days after hatching). Unhatched eggs remaining in the nest at the time of banding were considered nonviable. Nest checks, nestling banding, and removal of unhatched eggs usually required <20 min.

Eggs removed from nests were transported to the

Fig. 1. Warren G. Montague (right) holds an artificial bird box containing two eggs. A nylon stocking is fitted over the end of the flexible hose of a portable vacuum. The hose is inserted into the opening and down inside the cavity to the eggs. Suction from the vacuum will allow safe retrieval of the eggs. The same technique and equipment were used to remove unhatched eggs of Red-cockaded Woodpeckers in 1992.

Department of Biological Sciences at the University of Arkansas in Fayetteville, Arkansas. The eggs were measured and contents examined microscopically. Egg contents were preserved in formaldehyde and eggshells were retained.

Results

During the 1991 and 1992 nesting seasons, 92 eggs were laid in 27 nesting attempts in the Ouachita NF; of these, 18 (19%) failed to hatch (Neal, 1992). When viewed in the cavities, eight unhatched eggs were judged to be average in size and six less than average size (Tables 1, 2); the remaining four eggs disappeared before size was noted. The six small eggs (Tables 1, 2) were laid in five nests (6 of 92 eggs laid during 5 of 27 nesting attempts). Small eggs therefore constituted 6.5% of total eggs laid; 18.5% of total clutches included at least one of these small eggs.

In 1992 seven eggs were removed from seven different nests in four woodpecker nesting areas in Arkansas and Oklahoma; six were available for analysis (Table 3). Of these six, three showed some embryological development (Table 3; Nos. 1, 2, 4) and three showed no signs of development (Nos. 3, 5, 6). One of the six eggs (No. 2) was larger than the average size for Red-cockaded Woodpeckers, and two (Nos. 3, 4) were smaller than average. A seventh unhatched egg was successfully removed from a nest cavity in the Ouachita NF, but was dropped and broken. While it could not be salvaged for more detailed evaluation, gross visual examination did not indicate any embryological development.

Discussion

Unusually small, or runt, eggs have been reported in several species of birds, including North American woodpeckers (Koenig, 1980). It appears that unusual-sized eggs are infrequent in nests of Red-cockaded Woodpeckers. Jerome Jackson examined 60 apparently normal clutches before observing a clutch with one unusually large egg and three unusually small eggs (Ramey and Jackson, 1979). Only 1.33% of 75 eggs of Red-cockaded Woodpeckers in museum collections were runts (Koenig, 1980). In North Carolina 23 eggs of Red-cockaded Woodpeckers (1.1% of eggs seen) were runts. It appears that production of small eggs in the Ouachita NF (6.5% of all eggs laid) occurs

more frequently when compared to other populations of the woodpecker.

Table 1. Production of unhatched eggs of Red-cockaded Woodpeckers in the Ouachita National Forest in 1991.

Compartment/ stand[1]	Clutch size	Unhatched eggs, average size	Unhatched eggs, small size
323/13	4	1	0
323/14	4	1	0
862/25	4	1	0
1244/12	5	1	1
1252/26	4	0	1

[1]Compartments and stands are locations as designated in the Ouachita National Forest.

Table 2. Production of unhatched eggs of Red-cockaded Woodpeckers in the Ouachita National Forest in 1992.

Compartment/ stand[1]	Clutch size	Unhatched eggs average size	Unhatched eggs, small size
323/14	4	0	2[2]
323/23	3	1	0
326/14	4	1	0
1244/12	4	1	0
1274/9	4	0	1
1261/8	2	1	1

[1]Compartments and stands are locations as designated in the Ouachita National Forest.

[2]One small egg hatched, but nestling died within seven days; second small egg did not hatch.

Table 3. Unhatched eggs removed from nests of Red-cockaded Woodpeckers in Arkansas and Oklahoma in 1992[1].

No.	Site[2]	Size (mm)	Comment
1.	MCWA	23.3 x 17.8	Fertile egg with blastoderm evident; development ceased early
2.	CEF	25.4 x 19.0	Fertile egg; embryo started to develop, then stopped
3.	ONF	22.7 x 15.65	No development evident; yolk and albumen appeared normal
4.	ONF	20.09 x 10.51	Well-developed embryo; no yolk remained in very small egg
5.	ONF	24.9 x 17.5	No development evident; stress marks on shell
6.	PCNA	24.88 x 17.0	No development evident

[1]A seventh egg was dropped and broken after removal from the nest.

[2]Sites of nests of Red-cockaded Woodpeckers are abbreviated as follows: ONF = Ouachita National Forest; MCWA = McCurtain County Wilderness Area; CEF = Crossett Experimental Forest; PCNA = Pine City Natural Area.

Runt eggs appeared more frequently in clutches of cooperatively breeding Acorn Woodpeckers (*Melanerpes formicivorus*) than in clutches of other North American woodpeckers (Koenig, 1980; Koenig and Mumme, 1987). Four percent of eggs were runts and these were laid in 11.2% of Acorn Woodpecker nests (Koenig and Mumme, 1987). Koenig (1980) hypothesized that the relatively high incidence of runt eggs in Acorn Woodpeckers might have resulted from disturbance during the laying period, especially due to contact at the nest site between communally nesting females. Red-cockaded Woodpeckers do not nest communally. If production of small eggs is a result of disturbance at the nest site, some of the small eggs produced in the Ouachita NF may be due, in part, to unsettled social conditions at the onset of the nesting season.

Management of Red-cockaded Woodpeckers now includes translocation techniques in which unmated birds (often subadult females, or helper males, or both) are captured and moved into appropriate clusters of cavity trees where either a male, female, or birds of both sexes are lacking. This technique, which increases the effective number of breeding pairs, has been employed in the Ouachita NF since 1990.

On 18 March 1992, an unmated subadult female Red-cockaded Woodpecker was captured in compartment 862 and moved to an unmated adult male in compartment

323. The augmentation was successful, since between 28 April and 3 May the female laid four eggs, including two runt eggs (Table 2). A runt egg was also laid in a clutch that resulted from another translocation (Table 2, compartment 1274). Runt eggs were laid in these nests for unknown reasons, but unsettled social conditions provide a possible explanation.

Nest monitoring results in the Ouachita NF indicate hatching success rates that are within the range reported elsewhere for Red-cockaded Woodpeckers. In the Ouachita NF in 1991 and 1992, 81% of the eggs laid hatched (Neal, 1992). In South Carolina hatching success was 75% (Lennartz et al., 1987). In North Carolina at least 7.1% of eggs observed failed to hatch (range 5.5 to 12.1%); this figure was considered an underestimation since the birds themselves may have removed some eggs prior to the nest checks (M.S. LaBranche and J.R. Walters, pers. comm.). In Florida Ligon (1970) reported that 95% of eggs hatched.

Small, isolated populations of Red-cockaded Woodpeckers are susceptible to loss of heterozygosity, which could reduce the species ability to adapt to changing environmental conditions or other disturbances (Stangel et al., 1992). Embryological data could prove useful in recovery work. Efforts like egg exchanges or egg "cross-fostering" could improve heterozygosity in isolated populations. As with other endangered species (Wood and Collopy, 1993), induced renesting could potentially increase reproductive outputs. Determination of egg fertility rates or of stages of embryological development in unhatched eggs could help in assessing potential adverse impacts of nest monitoring. If production of small eggs is associated with unsettled social conditions, the timing of augmentations could be adjusted to improve nesting success.

Our technique for extraction of unhatched eggs could be easily incorporated as a routine procedure employed at the time nestlings are removed from cavities for banding. Vacuum suction was sufficient to hold the egg in the nylon stocking pouch. No eggs were damaged during removal from the nest cavity using the technique described here.

Acknowledgements

Support for this project was provided by the Poteau Ranger District of the Ouachita National Forest, the University of Arkansas Department of Biological Sciences and the Arkansas Cooperative Fish and Wildlife Research Unit. Field work in McCurtain County Wilderness Area was aided by John Skeen and Earl Stewart; in the Crossett Experimental Forest by John McLemore and Bruce Walsh; and in Pine City Natural Area by William Shepherd.

Literature Cited

Bent, A.C. 1939. Life histories of North American woodpeckers. Bull. 174, U.S. Nat. Mus., pp. 72-79.

James, D.A. and **J.C. Neal.** 1986. Arkansas birds, their distribution and abundance. Univ. of Ark. Press, Fayetteville. 402 pp.

James, D.A. and **J.C. Neal.** 1989. Update of the status of the Red-cockaded Woodpecker in Arkansas. Final Report, Project E-1, Ark. Game & Fish Comm., Little Rock. 18 pp.

Koenig, W.D. 1980. The incidence of runt eggs in woodpeckers. Wilson Bull. 92:169-176.

Koenig, W.D. and **R.L. Mumme.** 1987. Population ecology of the cooperatively breeding Acorn Woodpecker. Mono. pop. ecol. 24, Princeton Univ. Press, Princeton, N.J. 435 pp.

Lennartz, R.L., R.G. Hooper and **R.F. Harlow.** 1987. Sociality and cooperative breeding of Red-cockaded Woodpeckers, *Picoides borealis*. Behav. Ecol. Sociol. 20:77-88.

Ligon, J.D. 1970. Behavior and breeding biology of the Red-cockaded Woodpecker. Auk 87:255-278.

Ligon, J.D., P.B. Stacey, R.N. Conner, C.E. Bock and **C.S. Adkisson.** 1986. Report of the American Ornithologists' Union Committee for the Conservation of the Red-cockaded Woodpecker. Auk 103:848-855.

Masters, R.E., J.E. Skeen and **J.A. Garner.** 1989. Red-cockaded Woodpecker in Oklahoma: an update of Wood's 1974-77 study. Proc. Okla. Acad. Sci. 69:27-31.

Montague, W.G., J.C. Neal, J.E. Johnson and **D.A. James.** 1993. Techniques for excluding southern flying squirrels from cavities of Red-cockaded Woodpeckers. *In* Red-cockaded Woodpecker symposium III: species recovery, ecology and management (Costa, R., D.L. Kulhavy, and R.G. Hooper, eds.), Charleston, SC.

Neal, J.C. 1992. Factors affecting breeding success of Red-cockaded Woodpeckers in the Ouachita National Forest. M.S. thesis, Univ. of Arkansas, Fayetteville. 96 pp.

Neal, J.C. and **W.G. Montague.** 1991. Past and present distribution of the Red-cockaded Woodpecker and its habitat in the Ouachita Mountains, Arkansas. Proc. Ark. Acad. Sci. 45:71-75.

Neal, J.C., W.G. Montague and **D.A. James.** 1993. Climbing by black rat snakes on cavity trees of Red-cockaded Woodpeckers. Wildl. Soc. Bull. 21:160-165.

Ramey, P. and **Jackson, J.A.** 1979. Unusually large and small eggs in a Red-cockaded Woodpecker clutch. Inland Bird Band. 51:66-67.

Stangel, P.W., M.R. Lennartz and **M.H. Smith.** 1992. Genetic variation and population structure of Red-cockaded Woodpeckers. Conservation Biol. 6:283-292.

Withgott, J.H., J.C. Neal and **W.G. Montague.** 1993. A technique to deter climbing by rat snakes on cavity trees of Red-cockaded Woodpeckers. *In* Red-cockaded Woodpecker Symposium III: species recovery, ecology and management (Costa, R., D.L. Kulhavy and R.G. Hooper, eds.), Charleston, SC.

Wood, P.B. and **M.W. Collopy.** 1993. Effects of egg removal on Bald Eagle productivity in northern Florida. J. Wildl. Manage. 57:1-9.

Effects of Domestic Wastewater Effluent on the Water Quality and Aquatic Macroinvertebrates in a Sharp County, Arkansas Stream

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Abstract

The purpose of this study was to determine whether the effluent of the Ash Flat Wastewater Treatment Plant changes the water quality or aquatic macroinvertebrate community structure of North Big Creek. Weekly water samples were analyzed for pH, N, P, COD, TSS and fecal coliform bacteria from 17 June to 19 August 1992. Aquatic macroinvertebrates were collected biweekly using a Turtox Indestructible™ Dip Net, and density indices were calculated. Station 1, above the effluent, was a spring habitat. Fecal coliform, N, P, TSS and COD values were higher at this station, while the aquatic macroinvertebrate community was relatively simple. The effluent impact upon Station 2 was most obvious from the persistent presence of foam and filamentous algae. Moderating water temperature and enhanced nutrient supply has resulted in a more complex aquatic macroinvertebrate community with a lower numerical standing crop.

Introduction

To our knowledge, no studies have been made on the aquatic macroinvertebrates of North Big Creek. The purpose of this study was to determine if the effluent of the Ash Flat Wastewater Treatment Plant changes the water quality or aquatic macroinvertebrate community structure of this stream. The treatment plant, an extended aeration type, was installed in 1986, with a flow capacity of 350,000 l per day.

North Big Creek arises in northwest Sharp and southeast Fulton Counties. If flows southeasterly through Ash Flat to its confluence with the Strawberry River about 3.2 km north of Poughkeepsie, or approximately 1.6 km west of the St. Hwy 58 bridge. Its drainage lies completely within the Salem Plateau of the Ozark Mountains Physiographic Province.

Within the study area, North Big Creek is a third order stream. It is spring fed as is evidenced by the extensive growth of water cress, particularly at the upper end of the study area. The stream has a substrate of rock, sand, gravel, silt and organic mud. Its banks are at times steep, and either lined with rock outcroppings or eroded. Frequently, vegetation grows to the water's edge. Vegetation along the banks includes grasses, oak, willow, elm, hickory, sycamore, sweetgum, birch, cottonwood and hackberry. Climax vegetation is oak-hickory hardwood forest. The soil type is Gepp-Doniphan. It is well drained, gently sloping to steep, deep, very cherty and cherty soils. The Gepp series consists of deep, well drained, moderately permeable soils on hilltops and hillsides. The soils are formed in clayey residuum and in places in colluvium over cherty limestone bedrock. Slope ranges from 3 to 40%. Doniphan soils are on adjacent side slopes and broad ridgetops. These have a clayey control section, and base saturation is less than 35% (Soil Conservation Service, 1984a, 1984b).

Materials and Methods

Sample collections were made on North Big Creek between 17 June and 19 August 1992. The upstream collection site (Station 1), about 1 km above the effluent, was in the southern part of Ash Flat just east of the U.S. Hwy 167 bridge (SE1/4NE1/4 S15, T18N, R6W). The downstream collection site (Station 2), about 2 km below the Ash Flat Wastewater Treatment Plant (NW1/4SW1/4 S14, T18N, R6W), was east of Ash Flat just north of the St Hwy 354 bridge (SW1/4SW1/4 S12, T18N, R6W). Water samples were taken weekly (approximately) at each station for ten weeks. Each sample was analyzed for pH, nitrogen and phosphate using a Hach test kit (Water Analysis Handbook, 1982). Fecal coliform, chemical oxygen demand (COD), and total suspended solids (TSS) were analyzed by the Batesville Wastewater Treatment Plant. Other data recorded included: air and water temperature using a standard mercury thermometer, time, depth of collection, visual (presence of oil, foam, etc.) and amount of rain in the week prior to the collection. The Permit Compliance System (PCS) Facility Report (1992) for the City of Ash Flat was obtained from the Arkansas Department of Pollution Control and Ecology for the study period.

Aquatic macroinvertebrates were collected approximately every two weeks at each station using a Turtox

Indestructible™ Dip Net. Each sample was standardized by lasting for 1.5 man-h. An attempt was made to sample all microhabitats. The invertebrates were manually sorted from the materials and preserved in 70% ethanol. After identification all specimens were catalogued and housed in the Aquatic Macroinvertebrate Collection of the Arkansas State University Museum of Zoology (ASUMZ).

Shannon Diversity, Simpson Dominance, Shannon-Wiener Diversity, H' max and Evenness values were calculated using the AQUATIC ECOLOGY-PC disc of Oakleaf Systems, Decorah, IA. Simpson's Index of Diversity corresponds to the number of randomly selected pairs of individuals that must be drawn from a community in order to have an even chance of obtaining a pair with both individuals of the same species. It, therefore, expresses the dominance of or concentration of abundance of the one or two most common species of the community. Conversely, the Shannon-Wiener Diversity Index expresses the relative evenness of the abundances of all the species. Further, it is relatively independent of sample size. H' max is a calculated theoretical maximum diversity. The base 2 logarithm was selected for calculating diversity indices, as it is the most commonly utilized log (Cargill and Harp, 1987).

Results and Discussion

Rainfall varied from 0-9 cm per wk during the study period and had no discernable effect upon our results. The pH values were similar at both stations, with a mean of 7.2. Fecal coliform values were always higher at Station 1, on average by a factor of 4 (461.5/100 ml vs. 119.0/100 ml). Mean reactive phosphate values were 29% higher (mean = 0.49 vs. 0.38 mg/1) and mean nitrate values were 25% higher (mean = 0.35 vs. 0.28 mg/1) at Station 1. TSS and COD values were slightly higher at Station 1 (3.7 vs. 3.3 mg/1 and 14 vs. 12.2 mg/1 respectively). Finally, water temperature at Station 1 was 1-3°C cooler than at Station 2.

Station 1 was dominated by a spring habitat characterization. The aquatic macroinvertebrate community here had fewer taxa, more organisms and a less balanced distribution of organisms within those taxa (Tables 1, 2). Over 58% of the individuals collected were of the detritivorous snail *Campeloma*. This snail was favored by the extensive bed of water cress, while the cooler water temperatures discourage establishment by several taxa.

The impact of the effluent from the treatment plant on the stream is most obvious from the persistent presence of foam and moderate concentrations of filamentous algae at Station 2. The algal mats are apparently incorporating the nitrogen and phosphorous, resulting in lower values for these parameters in the water column. The treatment plant chlorinates the effluent, and this procedure reduces the fecal coliform count at least as far downstream as Station 2. The chlorine, however, did not impact the aquatic macroinvertebrate community at this station. Rather, the moderating water temperature and enhanced nutrient supply has allowed the development of a more complex, stable community here. Because the community structure is more balanced, the greater interplay of predation/competition results in lower numerical standing crop.

Two specimens collected at Station 2 are noteworthy. *Dixella* is quite infrequently collected in Arkansas and is represented by fewer than a dozen specimens in the ASUMZ. The single specimen of *Tropisternus ellipticus* collected is the eighth known for the state, the second specimen for Sharp County (Harp and Neasbitt, 1992).

Acknowledgements

We gratefully acknowledge the assistance of Leonard and Gayle Moss in the field collections and Batesville Wastewater Treatment Plant in analyzing water samples.

Literature Cited

Cargill, K. and **G.L. Harp.** 1987. The effect of city effluent on the diversity of aquatic macroinvertebrates of Sugar Creek, Clay County, Arkansas. Proc. Ark. Acad. Sci. 41:100-102.

Harp, G.L. and **W.H. Neasbitt.** 1992. A synopsis of the genus *Tropisternus* (Coleoptera: Hydrophilidae) in Arkansas. Proc. Ark. Acad. Sci. 46: 101-102.

Permit Compliance System Facility Report, City of Ash Flat. 1992. Arkansas Dept. of Pollution Conrol and Ecology, Little Rock, Arkansas. June-August 1992.

Soil Conservation Service. 1984a. Soil survey of Fulton and Izard Counties Arkansas. U.S. Dept. Agric. Little Rock, AR 122 pp.

Soil Conservation Service. 1984b. Soil survey of Sharp County Arkansas. U.S. Dept. Agric. Little Rock, AR 111 pp.

Water Analysis Handbook. 1982. Hach Company. Loveland, CO. pp. 2-182, 2-229, and 2-241.

Table 1. Aquatic macroinvertebrates expressed as number collected/7.5 h at North Big Creek June-August 1992.

Taxa	Station 1	Station 2
Spongillidae	1	0
Dugesia	12	3
Oligochaeta	8	2
Branchiobdellidae	1	0
Hirudinea	2	1
Batrachobdella	1	0
Helobdella	1	2
Placobdella	1	0
Ferissia	0	2
Physa	77	120
Gyraulus	1	0
Campeloma	1043	576
Corbicula fluminea	8	15
Sphaeriidae	65	43
Anodonta grandis	0	1
Hydracarina	3	5
Lirceus	14	0
Hyalella azteca	60	43
Orconectes	141	62
Baetidae	2	3
Baetis	5	9
Caenis	35	55
Ephemerella	0	2
Hexagenia	0	1
Heptagenidae	0	1
Heptagenia	0	1
Nixe	1	0
Stenonema	5	61
S. femoratum	6	2
S. interpunctatum	4	12
S. mediopunctatum	1	12
S. pulchellum	2	0
S. terminatum	2	0
Choroterpes	1	13
Isonychia	0	11
Tricorythodes	1	46
Basiaeschna janata	21	8
Stylogomphus albistylus	4	0
Libellulidae	0	1
Macromia	0	1
Calopteryx maculata	1	0
Hetaerina americana	10	24
Coenagrionidae	1	1
Argia	4	6
Enallagma	12	19
Ischnura	9	4
Perlidae	1	0
Acroneuria	6	3
Anacroneuria	0	1
Neoperla	1	0
Phasganophora	0	1
Neogerris	0	1
Pheumatobates	0	1
Trepobates	1	2
Hebrus	0	1
Mesovelia	5	17
Neoplea	1	0
Microvelia	1	15
Rhagovelia	2	22
Corydalus cornutus	2	26
Sialis	0	3
Trichoptera	2	0
Helicopsyche (p)*	35	4
Cheumatopsyche	13	7
Hydroptilidae	1	0
Pycnopsyche	2	0
Chimarra	9	0
Petrophilia	3	4
Lixus (a)	0	1
Helichus (a)	1	2
Hydroporous (a)	1	2
Uvarus (a)	1	0
Dubiraphia (a)	2	2
Dubiraphia (1)	0	1
Optioservus (a)	0	1
Stenelmis	2	81
Dineutus (1)	0	3
Peltodytes dunavani (a)	0	1
P. duodecimpunctatus (a)	1	21
P. litoralis (a)	11	10
P. sexmaculatus (a)	0	6
Berosus (a)	1	3
Enochrus pygmaeus nebulosus (a)	0	2
Helophorous (a)	1	0
Paracymus (a)	1	2
Tropisternus (1)	2	8
Tropisternus ellipticus (a)	0	1
Lutrochus laticeps (a)	0	1
Ectopria nervosa	0	1
Psephenus herricki	33	27
Scirtes (1)	0	1
Ceratopogonidae	8	3
Chaoborus	0	1
Chrionomidae	54	55
Dixella	0	1
Simulium	7	0
Stratiomys	0	1
Tipula	3	1
Total no. of organisms	1780	1515
Total no. of taxa	70	77

*(a) denotes adult stage, (1) denotes larval stage, (p) denotes pupal stage

Table 2. Community and nested (combined) statistical values for North Big Creek, 1992.

Parameter	Station 1	Station 2
Number of Taxa	70	77
Mean no. of taxa/sample	29	36
Mean numerical standing crop	356	303
Simpson Diversity Index	0.643	0.836
Simpson Dominance	0.357	0.164
Shannon-Weiner Diversity Index	2.847	4.000
H' max	6.149	6.285
Evenness (H' / H' max)	0.463	0.636

Range Extension of the Paleback Darter

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Abstract

Surveys from 1990 through 1992 resulted in a significant range extension of the paleback darter, *Etheostoma pallididorsum*, which is endemic to the Ouachita Mountains. Prior to 1990, it had only been collected in the upper Caddo River drainage and a tributary to the Ouachita River below Lake Ouachita. The collections that extended this darter's range occured in tributaries of the Ouachita River above Lake Ouachita.

Introduction

The paleback darter (*Etheostoma pallididorsum*) is endemic to the Ouachita Mountains in Arkansas (Robison and Buchanan, 1988). Prior to 1990 paleback darters had been collected only in the Caddo River drainage and one tributary of the Ouachita River below Lake Ouachita (Robison, 1974; 1980). Concern about the future of the species arose from its limited distribution and small population size. It was considered rare by the Arkansas Natural Heritage Commission in 1990 and sensitive by the United States Forest Service. (USDA Forest Service, 1990a).

Study Area and Methods

Surveys were conducted in Montgomery, Garland, and Polk counties, Arkansas, in tributaries of the Ouachita and Caddo Rivers that are within boundaries of the Caddo and Womble Districts of the Ouachita National Forest. These surveys were made from 1990-1992 by fisheries biologists from the USDA Forest Service and US Fish and Wildlife Service. Stream sampling was conducted with a Smith-Root Electofisher Model 12 backpack shocker. One to three people used dip nets to collect the stunned fish. Sampling distance averaged 0.4 km and each site was usually in a separate perennial tributary.

From 1990-1992, 41 sites in tributaries of the Caddo River drainage were sampled. These included eight of 17 locations where paleback darters had been previously recorded, plus seven spawning sites (Robison and Harp, 1981; Robison and Buchanan, 1988; USDA Forest Service, 1990a). From 1990-1992, 50 sites in the Ouachita River drainage were sampled. Sampling was also conducted at 15 sites of the Little Missouri River and its tributaries.

Most sites were sampled as baseline fish surveys and not just for occurrence of paleback darters. All fish collected in the Ouachita River drainage were ranked according to number collected. At each site, two to four voucher specimens of each fish species including paleback darters were retained and fixed in 10% formalin for three days, washed in tap water for three days and preserved in 50% isopropyl alcohol. Specimens were identified with standard keys (Robison and Buchanan, 1988); additionally, paleback darters were verified by Dr. Henry Robison. All preserved fish were kept at the Caddo and Womble Ranger Districts.

Results

Nine known paleback darter spawning areas were recorded prior to our study (Robison and Harp, 1981; Robison and Buchanan, 1988; USDA Forest Service, 1990a). Two spawning areas had been eradicated by 1990 due to residential construction.

We collected paleback darters in numerous locations in the Caddo River drainage. Of the 41 sites sampled, paleback darters were found in 30 sites: 1) 15 new sites in the Caddo River drainage (Table 1); 2) in all eight sites sampled that were previously known to have populations; and 3) in all seven previously known spawning sites.

Table 1. New locations for paleback darters in the Caddo River drainage, 1990-1992. Each listing represents a separate perrenial stream. Paleback darters had been found prior to 1990 in the Caddo River and in Lick Creek at different locations than listed below.

T3S R26W S29; T3S R25W S30	Caddo River
T3S R26W S20, S23	Lick Creek
T3S R26W S23	Trib. to Lick Creek
T3S R26W S23	Trib. to Lick Creek
T3S R25W S18, S29	Hamilton Creek
T3S R25W S21	Trib. to Lick Creek
T3S R25W S17	Harvey Branch
T4S R26W S9	Trib. to Polk Creek
T4S R26W S3	Trib to Polk Creek
T4S R26W S1	Trib. to Polk Creek
T4S R26W SI, S6	Trib. to Polk Creek

Our surveys extended the known distribution of this darter into nine tributaries of the Caddo River drainage. Distribution information of the paleback darter prior to 1990 was derived from Robison and Harp (1981), Robison and Buchanan (1988), and the USDA Forest Service (1990a).

In the Quachita River drainage, paleback darters were found in 13 of the 50 sites sampled (Table 2). These surveys extended the range of this darter into seven tributaries of the Quachita River above Lake Quachita and into four tributaries of the Quachita River below Lake Quachita.

Table 2. New locations for paleback darters in the Ouachita River drainage, 1990-1992. Each listing represents a separate perennial stream.

T3S R23W S16	Trib. to Mazarn Creek
T3S R27W S8	Trib. to Kate's Creek
T3S R27W S3, S10	Bill Hill Creek
T3S R23W S16	Wake Creek
T3S R23W S21	Blue Creek
T3S R28W S23	Trib. to Big Fork
T3S R28W S14, S34	Big Fork
T3S R27W S18	Trib. to Kate's Creek
T3S R27W S18	Kate's Creek
T2S R28W S34	Trib. to Big Fork
T3S R23W S16	Trib. to Mazarn Creek

As a result of this study and previous studies, paleback darters are now known from 17 tributaries (and seven spawning sites) within the Caddo River drainage and from 12 tributaries in the Quachita River drainage. No additional spawning areas were located during the present study. No paleback darters were found in the Little Missouri River drainage.

Compared to numbers of other species of fish collected, numbers of paleback darters collected were low. Paleback darters were the only species collected in a few upland small streams, but in larger streams their numbers were the lowest compared to other species. The highest number of paleback darters collected at any site was 12; but the average number taken from sites was four. In tributaries of the Quachita River, numbers of other fish species found with the paleback darter ranged from four to 16 (mean = seven species). The species most often immediately found with the paleback darter were (in decreasing order): orangebelly darter (*Etheostoma radiosum*), creek chub (*Semotilus atromaculatus*), longear sunfish (*Lepomis megalotis*), central stoneroller (*Campostoma anomalum*), and striped shiner (*Luxilus chrysocephalus*). Ranking number of fish commonly taken at sites where paleback darters were found was as follows (in decreasing value): creek chub, central stoneroller, striped shiner, longear sunfish, green sunfish (*Lepomis cyanellus*), orangebelly darter.

Paleback darters inhabit margins of pools and side channels of clear, moderate-to-high gradient, perennial streams and are occasionally associated with vegetation over mud substrate (Robison, 1980). During this study, paleback darters were typically found in these habitats during the non-spawning season. However, during the fall and winter (spawning season), we found paleback darters in both drainages occasionally in fast-moving water (0.3 m in depth) or associated with aquatic vegetation.

Discussion

This work extends the range of the paleback darter in tributaries of the Caddo and Ouachita rivers. Many of the small upper Ouachita River tributaries sampled in this study had never been previously sampled and likely explains the range extension. This darter is more widespread than previously thought; however, numbers collected at all sites were low. Hambrick and Robison (1979) also found population sizes to be low in the Caddo River drainage. The fish found with the paleback darter in the Ouachita River drainage are quite similar to findings by Robison and Harp (1981) in the Caddo River drainage.

Paleback darters found in the autumn and winter in fast moving water were probably moving into spawning areas, including spring heads and seeps. Paleback darters spawn mainly from February through March (Robison and Buchanan, 1988). Known spawning areas are vegetated (pers. obs.). Most of the known paleback darter spawning areas become intermittent and dry up during summer months (pers. obs.). The presence of this darter in two areas in the autumn and winter in a vegetated small first order stream and in a spring may represent two previously unknown spawning sites.

These surveys were conducted to protect aquatic resources according to the Amended Land and Resource Management Plan for the Ouachita National Forest (USDA Forest Service, 1990b). Aquatic surveys are essential to determine species that are present and the status of these species. This information aids in making informed management decisions that can prevent trends toward endangerment that would result in Federal listing (USDA Forest Service, 1990 b, 1990c).

Acknowledgements

This study was funded by the USDA Forest Service. Appreciation is expressed to Womble and Caddo District

Rangers, Robert Raines and James Watson, as well as James Stewart, John Harris, Henry Robison, Carl Racchini, Donny Harris, Richard Anderson, James Johnson, Womble District 1992 Youth Conservation Corps and Connie Smith. We appreciate comments by Joe Neal on an earlier draft of this manuscript.

Literature Cited

Hambrick, P.S. and **H.W. Robison.** 1979. Life history aspects of the paleback darter, *Etheostoma pallididorsum* (Pices: Percidae) in the Caddo River system, Arkansas. Southwest. Nat. 24 (3):475-484.

Robison, H.W. 1974. An additional population of *Etheostoma pallididorsum* Distler and Metcalf in Arkansas. Amer. Midl. Nat. 91 (2):478-479.

Robison, H.W. 1980. *Etheostoma pallididorsum* Distler and Metcalf, Paleback darter. *In*: D.S. Lee et al. Atlas of North America Freshwater Fishes. N.C. State Mus. Nat. Hist. Raleigh. p. 679.

Robison, H.W. and **T.M. Buchanan.** 1988. Fishes of Arkansas. Univ. Arkansas Press. 536 pp.

Robison, H.W. and **G.L. Harp.** 1981. A status report on the paleback darter, *Etheostoma pallididorsum* Distler and Metcalf, and upper Ouachita River endemic from Arkansas. Unpublished report. 26 pp.

USDA Forest Service. 1990a. Ouachita National Forest: Proposed, endangered, threatened, and sensitive species (PETS) database. Hot Springs, AR.

USDA Forest Service. 1990b. Amended land and resource management plan. Ouachita National Forest. Vol. 1. Hot Springs, AR.

USDA Forest Service. 1990c. Threatened, endangered, and sensitive species recovery and conservation: Action plan. Washington D.C.

The Role of Endophytes in Tall Fescue

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Abstract

Tall fescue (*Festuca arundinacea* Schreb.) is the most commonly grown cool season grass used for pastures in Arkansas. Most tall fescue contains a fungal endophyte (*Acremonium coenophialum* Morgan-Jones & Gams), which causes fescue toxicosis in livestock and costs cattle producers millions of dollars annually in lost production. Endophyte presence is known to reduce wild mammal populations in areas where tall fescue is prevalent. The endophyte spends its entire life cycle within the plant and is transmitted through the seed. The association is mutualistic with the plant providing nutrients for the endophyte and the endophyte conferring drought, insect, and nematode resistance to the plant. Several classes of alkaloids exist in endophyte-infected tall fescue including ergopeptides and lolines. The ergopeptides are animal toxins, whereas the lolines deter insects. Our present work is on elucidating physiological mechanisms explaining animal disorders and improved host drought tolerance due to endophyte, and on identifying endophyte strains that are not toxic to livestock but that improve drought and pest resistance in tall fescue.

*Published with the approval of the Director, Agriculture Experiment Station.

Introduction

Tall fescue (*Festuca arundinacea* Schreb.) is the most commonly grown cool season grass in Arkansas and is used for forage, turf and roadside erosion control. The presence of a fungal endophyte (*Acremonium coenophialum* Morgan-Jones & Gams) in tall fescue is associated with a condition in livestock called fescue toxicosis. The endophyte lives in a symbiotic relationship with the grass in which the fungus provides pest resistance and protection against drought for the host while the plant provides nutrition and a means of dissemination for the fungus. The endophyte-tall fescue association makes a significant impact on the landscape and land use of Arkansas owing to its high resistance to herbivory and environmental stress and to its enhanced agronomic attributes. The purpose of the paper is to summarize the current state of knowledge of aspects of tall fescue-endophyte association that involve cost to mammals and invertebrates and benefits to the host plant.

Plant/Endophyte/Animal Relationships

Incidence of Endophyte.--The principle tall fescue cultivar grown in Arkansas is "Kentucky-31" which was selected from a pasture population in Kentucky and was released in 1941. The cultivar grew and persisted on marginal land better than other cool season perennial grasses. As a consequence, Kentucky-31 was widely planted across the east-central and southeastern U. S.. Since over 90% of fescue pastures in the U. S. contain the endophyte (Shelby and Dalrymple, 1987), the original population probably contained the endophyte. Seventy eight percent of tall fescue plants examined from Arkansas pastures contained the endophyte (Daniels et al., 1985).

Endophytic fungi are common to many grass species (White, 1987). Many of the *Claviceps* spp. to which *A. coenophialum* is related produce conidia and ascospores. They parasitize grass leaves and inflorescences, reproduce sexually and disseminate spores to other plants (Clay, 1991). In contrast, *A. coenophialum*, which does not sporulate, lives between the cell walls of the plant in a mutualistic relationship and is spread through seed transmission by its host (Bacon and Siegel, 1988).

Fescue Toxicosis in Mammals.--The association between tall fescue, the presence of an endophyte and fescue toxicosis was made after measuring high endophyte infection rates in fields in which cattle (*Bos* spp.) were suffering from fescue toxicosis and low infection rates in fields where cattle showed no symptoms (Bacon et al., 1977). Fescue toxicosis symptoms which are particularly prominent during hot, humid weather are referred to as "summer slump" and "physiological distress". They include: 1) reduced weight gains; 2) lowered feed intake; 3) elevated body temperature; 4) increased breathing rate; 5) excess salivation; 6) increased time spent in shade or water; 7) lowered milk production; 8) rough hair coat; 9) reduced reproductive rates; and 10) lowered serum prolactin levels (Stuedemann and Hoveland, 1988). In addition, a condition referred to as "fescue foot", which is usually seen during cold weather, results in animals with sore feet or, in more severe cases, loss of extremities (Yates et al., 1979). Fescue toxicosis is estimated to cost U. S. cattle

producers over $600,000,000, annually (Hoveland, 1990).

Several alkaloids are reported in endophyte-infected tall fescue. The lolines (pyrrolizidine alkaloids) are believed to be effective insect deterrents (Yates et al., 1989) and may have a vasomotor effect on mammals (Oliver et al., 1990). The endophyte also produces ergot alkaloids, a group of compounds that have long been known to be mammalian toxins. These alkaloids include the ergopeptine alkaloids, of which ergovaline is the principle alkaloid, and lysergic acid derivatives (Lyons et al., 1986). In our laboratory, we have shown that ergopeptides will inhibit prolactin secretion *in vitro* (Hays et al., 1992). Using changes in tail temperature as an indicator of modification in peripheral blood flow, we have shown that ergopeptides and lysergic acid derivatives can induce peripheral vasoconstriction (Brown et al., 1993). These data suggest that the ergot alkaloids are, in part, responsible for fescue toxicosis.

Four to five times more wild mammals were trapped on endophyte-free vs endophyte-infected tall fescue pastures (Pelton et al., 1991). This suggests that, as observed with livestock, growth or reproductive rates may be reduced in small mammals living on endophyte-infected fescue sods. At least part of the year, many small mammals would rely on fescue seed as a major portion of their diet. The highest concentration of ergot alkaloids found in the plant are in endophyte-infected seed. Wild birds (*Junco hyemalis*) selected endophyte-free fescue seed over endophyte-infected seed when offered the seed free choice (Clay, 1989). Depressed prolactin levels that wild birds incur from eating endophyte-infected seed may inhibit egg laying.

New Zealand researchers have associated the presence of an endophyte (*A. lolii*) in perennial ryegrass (*Lolium perenne* L.) with a tremorogenic condition in sheep called ryegrass staggers (Fletcher and Harvey, 1981). A neurogenic toxin, lolitrem B, has been isolated from endophyte-infected ryegrass and is believed to cause ryegrass staggers (Gallagher et al., 1981).

Insect and Nematode Deterrence.--The presence of endophyte in grasses has been shown to deter insect herbivory. When endophyte in perennial ryegrass was associated with outbreaks of ryegrass staggers, endophyte-free cultivars were planted. These cultivars were highly susceptible to attacks (Barker et al., 1984) from Argentine stem weevil (*Listronotus bonariensis* Kuschel). The insect deterrent in endophyte-infected perennial ryegrass is peramine, an alkaloid that is also found in endophyte-infected tall fescue (Siegel et al., 1990). High concentrations of pyrrolizidine (N-acetyl and N-formyl loline) alkaloids are found in endophyte-infected tall fescue (Bush et al., 1982). These alkaloids are produced by the plant in response to the endophyte presence and act as insect toxins (Yates et al., 1989).

Density of endophyte-free tall fescue stands are often decreased despite an apparent lack of mammalian or insect herbivory (Clay, 1991). Reduced plant competitiveness and persistence may be in part due to predation by root-feeding nematodes, especially in combination with drought stress (West and Gwinn, 1993). Incidence of the ectoparasite *Tylenchorhenchous acutus* Allen and endoparasite *Pratylenchus scribneri* Steiner were lower in field plots planted to endophyte-infected than endophyte-free tall fescue (West et al., 1988). Endophyte presence strongly inhibited reproduction of the endoparasite *Meloidogyne marylandi* Jepson and Golden in tall fescue roots (Elmi et al., 1990). The chemical agents in endophytic tall fescue affecting nematodes have not been identified.

Endophyte and Host Drought Resistance.--The presence of the endophyte in tall fescue increases drought stress tolerance and persistence, and hence expands the geographic range of adaptation of tall fescue (West and Gwinn, 1993). Tiller density in endophyte-free stands was 62% of endophyte-infected stands after a severe summer drought (West et al., 1993). Endophyte-infected plants exhibited leaf rolling sooner than endophyte-free plants of the same genotype during the onset of drought stress (Arachevaleta et al., 1989). The reverse or no difference was found in field trials (West et al., 1988, 1993). In greenhouse experiments, Elmi (1992) found that transpiration rate and stomatal conductance in endophyte-infected plants were lower than in endophyte-free plants when subjected to drought stress, indicating a short-term, drought postponement mechanism. Endophyte-infected plants showed increased survival after severe drought compared with noninfected plants (Elmi, 1992). Increased survival of endophyte-infected plants was associated with higher osmotic adjustment in the leaf growing zone suggesting an additional mechanism of drought tolerance at low water potential for longer-term stress. Increased persistence of tall fescue during drought due to endophyte presence is a major biological benefit to the plant and economic benefit to the pasture manager.

Beneficial Uses of Endophytes.--As part of the program to reduce the cost to Arkansas agriculture of fescue toxicosis we are screening a large number of germplasm sources of tall fescue from its regions of origin for low or no production of ergopeptine alkaloids and high levels of insect-deterring alkaloids. Our data indicate that there is a great deal of diversity in the alkaloid profiles of endophyte-infected plants. Work is presently underway to transfer endophytes producing no mammalian toxins into endophyte-free cultivars. The goal of this research is to produce a tall fescue-endophyte combination that is not toxic to livestock but that retainspest and drought resistance.

Acknowledgements

Rat prolactin I-6, RP-3 and antisera S-9 were obtained from the National Hormone and Pituitary Program. This work was supported by grants from the Arkansas Department of Higher Education, Southern Regional IPM (CSRS-USDA) and Research Center for Alternative Pest Control (CSRS-USDA).

Literature Cited

Arachevaleta, M., C. W. Bacon, C. S. Hoveland and **D. E. Radcliffe**. 1989. Effect of the tall fescue endophyte on plant response to environmental stress. Agron J. 81:83-90.

Bacon, C. W., and **J. K. Porter, J. D. Robbins** and **E. S. Luttrell.** 1977. *Epichloe typhina* from toxic tall fescue grasses. Appl. and Environ. Microbiol. 34:576-581.

Bacon, C. W. and **M. R. Siegel**. 1988. Endophyte parasitism of tall fescue. J. Prod. Agric. 1:44-55.

Barker, G. M., R. P. Pottinger, P. J. Addison and **R. A. Prestidge**. 1984. Effect of *Lolium* endophyte fungus infections on behavior to adult Argentine stem weevil. N. Z. J. Agric. Res. 27:271-277.

Brown, K. L., E. L. Piper, G. C. Duff and **Z. B. Johnson**. 1993. Effects of ergot alkaloids on tail temperatures of Holstein steers. J. Anim. Sci. 70 (Suppl. 1):32.

Bush, L. P., P. L. Cornelius, R. C. Buckner, D. R. Varney, R. A. Chapman, P. B. Burrus, II, C. W. Kennedy, T. A. Jones and **M. J. Saunders**. 1982. Association of N-acetyl loline and N-formyl loline with *Epichloe typhina* in tall fescue. Crop Sci. 22(5):941-943.

Clay, K. 1989. Trespassers will be poisoned. Natural History 9:8-14.

Clay, K. 1991. Fungal endophytes, grasses and herbivores.In P. Barbosa, V. A. Krischik and C. G. Jones (ed.) Microbial Mediation of Plant-Herbivore Interactions. p. 5, John Wiley and Sons, New York.

Daniels, L. B., E. L. Piper, B. J. Hankins, G. Gee, T. S. Nelson and **J. Gergerich.** 1985. Infestation level of the endophyte *Acremonium coenophialum* in fescue pastures in twenty-one Arkansas counties. Ark. Farm Res. 34(1):9.

Elmi, A. A. 1992. Physiological effects of endophyte and nematodes on water relations in tall fescue. Ph.D. diss. University of Arkansas, Fayetteville. DAI 53-08B, Diss Abstr. Order # 9237355.

Elmi, A. A., C. P. West, T. L. Kirkpatrick and **R. T. Robbins**. 1990. *Acremonium* endophyte inhibits root-knot nematode reproduction in tall fescue. Ark. Farm Res. 39(6):3.

Fletcher, L. R. and **I. C. Harvey**. 1981. An association of a *Lolium* endophyte with ryegrass staggers. N. Z. Vet. J. 29:185-186.

Gallagher, R. T., E. P. White and **P. H. Mortimer**. 1981. Ryegrass staggers: Isolation of potent neurotoxins lolitrem A and lolitrem B from staggers-producing pastures. N. Z. Vet. J. 29:189-90.

Hays, D. H., E. L. Piper, R. W. McNew and **A. S. Moubarak.** 1992. Effects of ergopeptide fraction on *in vitro* pituitary prolactin release. J. Anim. Sci. 70:(Suppl. 1)71.

Hoveland, C. S. 1990. Importance and economic significance of the *Acremonium* endophytes to performance of animals and grass plants. (Pp. 3-12) *In:* Acremonium /Grass Interactions, R. Joost and S. Quisenberry, eds. Elsevier.

Lyons, P. C., R. D. Plattner and **C. W. Bacon**. 1986. Occurrence of peptide and clavine ergot alkaloids in tall fescue grass. Science 232:487-489.

Oliver, J. W., R. G. Powell, L. K. Abney, R. D. Linnabary and **R. J. Petroski**. 1990. N-acetyl loline induced vasoconstriction of lateral saphenous vein (cranial branch) of cattle. Proc. of Int. Symp. on *Acremonium*/Grass interactions. p. 239. Nov. 3-7, New Orleans.

Pelton, M. R., H. A. Fribourg, J. W. Laundre and **T. D. Reynolds.** 1991. Preliminary assessments of small wild mammal populations in tall fescue habitats. Tenn. Farm & Home Sci. 160:68-71.

Shelby, R. A. and **L. W. Dalrymple.** 1987. Incidence and distribution of the tall fescue endophyte in the United States. Plant Dis. 71:783-786.

Siegel, M. R., G. C. M. Latch, L. P. Bush, F. F. Fannin, D. D. Rowan, B. A. Tapper, C. W. Bacon and **M. C. Johnson.** 1990. Fungal endophyte-infected grasses: Alkaloid accumulation and aphid response. J. Chem. Ecol. 16:3301-3315.

Stuedemann, J. A. and **C. S. Hoveland**. 1988. Fescue endophyte: history and impact on animal agriculture. J. Prod. Agric. 1:39-44.

West, C. P. and **K. D. Gwinn.** 1993. Role of *Acremonium* in drought and pest tolerances of grasses. N. Z. J. of Agric. Res. In Press.

West, C. P., E. Izekor, D. M. Oosterhuis and **R. T. Robbins.** 1988. The effect of *Acremonium coenophialum* on the growth and nematode infection of tall fescue. Plant Soil. 112:3-6.

West, C.P., E. Izekor, K.E. Turner and **A.A. Elmi.** 1993. Endophye effects on growth and pesistence of tall fescue along a water-supply gradient. Agron. J. 85:264-270.

White, J. F. Jr. 1987. Widespread distribution of endo phytes in the Poaceae. Plant Disease. 71:340-342.

Yates, S. G., J. C. Fenster and **R. J. Barlelt.** 1989. Assay of tall fescue seed extracts, fractions and alkaloids using the large milkweed bug. J. Agric. Food Chem.

37:354-357.

Yates, S. G., J. A. Rothfus, G. B. Garner and **C. N. Cornell.** 1979. Video thermometry for assay of fescue foot in cattle. Am. J. Vet. Res. 40:1192-1196.

Semi-Insulating Polysilicon Hetero- and Isotype Junctions on Silicon

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Abstract

The effects of nitrogen trifluoride in the gas stream during deposition of semi-insulating polysilicon (SIPOS) on the electrical characteristics of undoped (SIPSO)/p-Si, and n+-SIPOS/n-Si isotype junctions were investigated. The current-voltage charateristics of undoped SIPOS/p-Si heterojunctions exhabit a strong dependence on the oxygen content of the SIPOS film and depart from a hyperbolic sine behavior as the refractive index of the SIPOS increases.. The addition of nitrogen trifluoride decreases the current density of these undoped SIPOS/p-Si heterojunctions due presumably to the oxidation/hydrolysis of SiF species into SiO_2. The n+-SIPOS formed a rectifying isotype junction o n-Si. The forward current-voltage characteristics exhibit two distinct activation energies separated by a "kink" in the forward semi-logarithmic characteristics; one below the cut-in voltage and one above the cut-in voltage. The two activation energies result from the presence of interface states in the structures. However, the forward current-voltage characteristics of the fluorinated SIPOS isotype junctions exhibit no "kink" and only a single activation energy due, presumably, to hydrogen passivating the interfacial traps during the hydrolysis process.

Introduction

Semi-insulating polysilicon (SIPOS) films have been used primarily as a surface passivant for high-voltage semiconductor devices (Matsushita et al., 1976). The finite conductivity of the undoped SIPOS film provides a field-shield effect for the passivated surfaces; yet the conductivity is low enough that leakage current through the film is reasonably low for many device applications. Other applications include use as the insulating layer in a power SIPOS MISS device (Ang, 1988) and as thin film sheet resistance SIPOS resistors in CMOS SRAMs to replace the polysilicon decoupling resistors (Ong et al., 1991).

Assumin a "mosaic" model for the SIPOS as proposed by Tarng (1978), Bolt and Simmons (1987) concluded that carrier transport through undoped SIPOS was by thermionic emission (TE) of carriers over the grain boundries at temperatures above room temperature, while carrier transport below room temperature was by thermionic field emmission (TFE) by which significant tunneling through the barrier occurs. Arnold and Karins (1983) investigated the electrical properties of doped SIPOS films and proposed a spatial fluctuation of dopant concentration to explain the transition from thermally-activated to temperature-independent conductivity at high doping concentrations. Ong et al. (1991) reported that the conductivity activation energies (0.007-0.01 eV) of arsenic doped SIPOS films are lower than those of thin film polysilicon films (0.07-0.09 eV) for the same sheet resistance of 10^5 ohms/sq. They showed that thin-film SIPOS resistors were less sensitive to changes in temperature compared to their polysilicon counterpart. Ranade et al. (1991) reported that carrier conduction in SIPOS heterojunctions on silicon is mainly controlled by the SIPOS/p-Si interface. The forward characteristics of n+-SIPOS/p-Si heterojunctions display both a low and a high field activation energy with the difference attributable to the presence of interface states at the junction.

In this paper, the effects of nitrogen trifluoride on the electrical properties of undoped SIPOS/p-type crystalline silicon, and n+-SIPOS/n-Si isotype junctions are reported.

Materials and Methods

Boron-doped and phosphorus-doped <100> silicon substrates of 2-5 ohm-cm were used for undoped heterojunctions and n+-SIPOS/n-Si isotype junctions, respectively. After an initial H_2O_2 and H_2SO_4 (1:2 by volume) clean, an HF dip etch was performed to remove the chemical and native oxide left on the silicon. SIPOS was then deposited on these silicon substrates. Details of the process used to deposit SIPOS film by plasma-enhanced chemical vapor deposition have been described in a previous paper (Lai et al., 1990). Briefly, SIPOS films were deposited on the silicon substrates in a parallel-plate, capacitively coupled, 13.56 MHz Reinberg-type reactor (Texas Instrument A24C) PECVD reactor using a mixture of monosilane (SiH_4) and nitrous oxide (N_20) with a varying N_2O/SiH_4 ratio of 0.1-0.4. In some depositions, 0.5 sccm of nitrogen

trigluoride (NF_3) was added to the N_2O/SiH_4 mixture. A deposition power density of 25 mW cm^{-2} and a chamber pressure of 0.5 Torr were selected to maintain a stable plasma between the reactor electrodes to ensure reproducible film composition and uniformity. The thickness of the SIPOS was about 2000 Å. The refractive indices of the SIPOS films in this study varied from 1.8 to 2.9, with the refractive index of 2.9 corresponding to the N_2O/SiH_4 ratio of 0.1. The oxygen content in the SIPOS film with a refractive index of 2.9 was found to be about 15% using RBS. It should be noted that hydrolysis of SIPOS films occurs immediately after exposure to room ambient as the refractive index of the fluorinated SIPOS does not change with time after deposition.

SIPOS films were then implanted with arsenic for the n+-SIPOS/n-Si isotype junctions. The implant parameters were 1×10^{17} cm^{-2} at an implant energy of 150 keV. Annealing of the films was performed in a nitrogen ambient at 1000°C for 60 seconds in a computer-controlled Heatpulse 210-T rapid thermal processor. Rutherford backscattering (RBS) measurements revealed uniform arsenic profiles in the SIPOS film after rapid thermal annealing. The top electrode of the devices was aluminum, evaporated to a thickness of about 5000 Å in a thermal evaporator. Aluminum or silver paste was used as the ohmic contact on the backside of the samples.

Current-voltage measurements were performed using an HP4145A semiconductor parameter analyzer. Samples were placed in a MMR Technologies low temperature microprobe (LTMP-3) controlled by a MMR K-20 programmable temperature controller interfaced with a personal computer for temperature measurements.

Results and Discussion

Undoped Sipos/P SI Heterojunctions--Figure 1 shows the current density versus applied bias characteristics for a typical undoped SIPOS/p-Si heterojunction fabricated using SIPOS with a refractive index of 2.9 and without NF_3 in the deposition gas stream. The nonsymmetrical nature of the current-voltage data of the this device indicates that undoped SIPOS forms a heterojunction on p-type crystalline silicon. This is because SIPOS is n-type owing to the presence of donor states within its bandgap with the Fermi level pinned near and above the midgap (Tarng, 1978). It should be noted that the current-voltage characteristics of these undoped SIPOS/p-Si heterojunctions depart from hyperbolic sine behavior as the refractive index increases. Likewise, the current density versus applied bias characteristics of undoped SIPOS/p-Si heterojunctions fabricated using SIPOS with a refractive index of 2.9 and deposited with 0.5 sccm of NF_3 in the deposition gas stream depart from hyperbolic sine behavior. As can be seen, the forward current density of the fluorinated heterojunction is substantially lower than that of the unfluorinated, undoped SIPOS/p-Si heterojunction. Furthermore, the reverse current density saturates at a relatively low reverse bias. The addition of NF_3 during the SIPOS deposition favors the formation of SiF species (SiF, SiF_2, SiF_3, and $[SiF_2]_n$) in the SIPOS films. The open structure of the fluorinated SIPOS, due to a high concentration of the $[SiF_2]_n$ specie, favors the penetration of oxygen and water molecules into the network (Sanchez et al., 1993). As the SiF species hydrolyze, they are converted into SiO_2 in the SIPOS. Even through the refractive index of the SIPOS films deposited in the presence of NF_3 is similar to the SIPOS film deposited with no NF_3, the fluorinated SIPOS films contain a higher percentage of SiO_2 for the same amount of oxygen in the films.

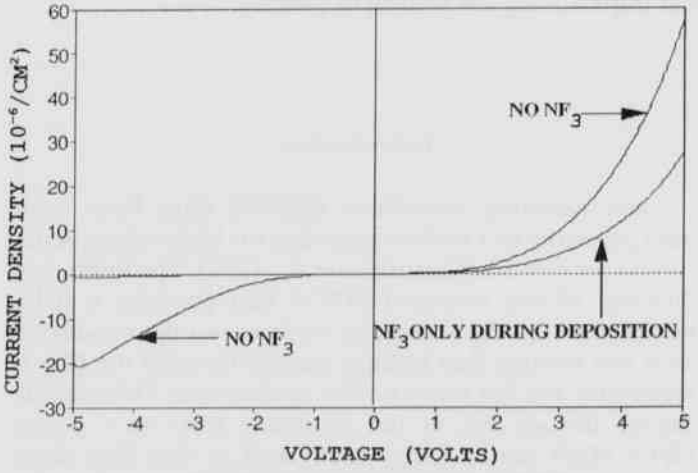

Fig.1. Current density versus applied voltage of a typical undoped and a fluorinated SIPOS/p-Si heterojunctions.

Figure 2 shows current density versus applied bias characteristics for temperatures from 260 K to 320 K for a typical heterojunction fabricated with undoped SIPOS (refractive index = 2.9) on p-type silicon. The current density increases with temperature for a given applied bias and increases with applied bias for a given temperature according to a hyperbolic sine function. At low applied biases, such that $V << 2gkT/q$, the current-voltage characteristic of the heterojunction can be expressed as (Ranade et al., 1991)

$$J = \frac{qVA^*T}{gk} e^{\frac{-\Phi_{bi}}{kt}}$$

where A* is the effective Richardson constant for silicon, g is the number of grains in series, Φ_{bi} is the barrier height, q is the electronic charge, T is the absolute temperature, k is the Boltmann constant, and V is the applied voltage. Figure 3 shows current density versus applied bias characteristics for temperatures from 260 K to 320 K of a typical heterojunction of undoped SIPOS (refractive index = 2.9) on p-type silicon with NF_3 added during the SIPOS deposition. It can be seen that the temperature dependence of its current-voltage characteristics is much weaker compared to those of undoped heterojunctions with no NF_3.

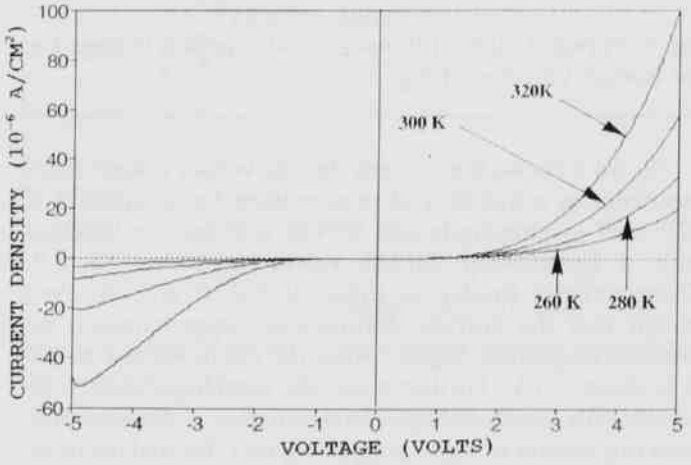

Fig. 2. Current density versus applied voltage with temperature as a parameter of a typical undoped SIPOS (R.I. = 2.9) on a p-type silicon heterojunction.

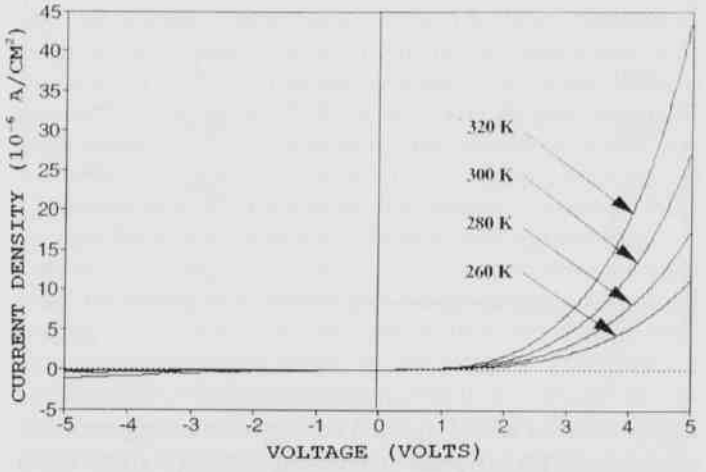

Fig. 3. Current density versus applied voltage with temperature as a parameter of a typical fluorinated SIPOS/p-Si heterojunction.

Figure 4 shows the (J/T) at V = 0.5 V versus reciprocal temperature plot for the undoped SIPOS/p-Si heterojunction diodes of Fig. 2 and Fig. 3. As shown, the (J/T) versus reciprocal temperature plot reveals two barrier heights Φ_{bi} for carrier conduction in the undoped heterojunction with no NF_3. A least-squares fit yields a Φ_{bi} of 0.27 eV for operating temperatures above 300 K and 0.04 eV below 300 K. These values are comparable to those reported by Bolt and Simmons (1987). The higher Φ_{bi} (above 300 K) suggests that carrier conduction is by thermionic emission, while below 300 K it is by thermionic field emission (Tarng, 1978), in which significant carrier tunneling through the oxide surrounding the silicon grains occurs. Furthermore, as the SIPOS refractive index decreases from 2.9 to 2.1, the high-temperature Φ_{bi} increases from 0.27 eV to 0.35 eV, while the low temperature Φ_{bi} increases from 0.04 eV to 0.07 eV. This is attributable to a thicker oxide barrier surrounding the silicon grains for a SIPOS film with a lower refractive index. Similar changes in high temperature Φ_{bi} have also been observed in bulk SIPOS films, although the high temperature Φ_{bi} in bulk undoped SIPOS films is considerably larger. The low temperature Φ_{bi} in bulk SIPOS films is very similar to that of heterojunctions since carrier tunneling is predominant. Therefore, carrier transport in the undoped SIPOS/p-Si heterojunction diodes appears to be controlled by the SIPOS/pSi interface. On the other hand, a barrier height of 0.11 eV is obtained for the undoped fluorinated SIPOS heterojunction. Thus, the undoped fluorinated SIPOS/p-Si heterojunction exhibits a single conduction mechanism for the temperature range considered. This is thought to be due to increased SiO_2 content in the fluorinated SIPOS film.

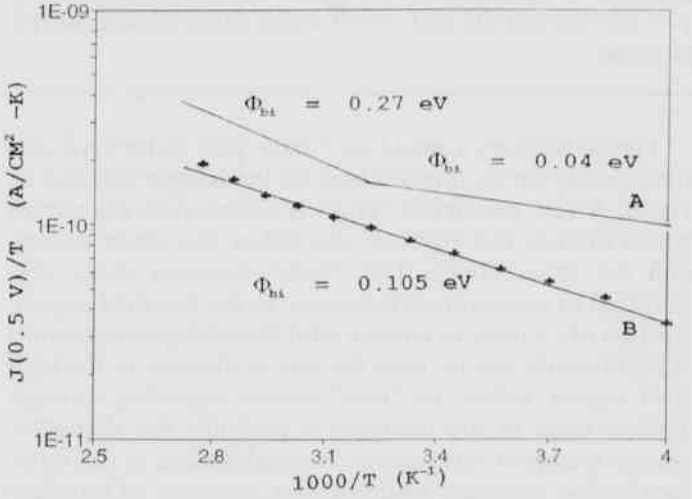

Fig. 4. (J/T) at V = 0.5 V versus reciprocal temperature of a typical undoped SIPOS (R.I. = 2.9) on a p-type silicon heterojunction.

N+-SIPOS/N-SI Isotype, Junction

Figure 5 shows current versus voltage characteristics as a function of temperature for a typical 1 X 10^{17} cm^{-2} arsenic-implanted n+-SIPOS/n-Si isotype junction with a SIPOS refractive index of 1.8. An exponential increase in current with forward bias is observed, indicating a rectifying junction. At room temperature, the cut-in voltage is about 3 V. The cut-in voltage is seen to decrease with increasing temperature because of an increasing recombination current component at the interface due to shallow states. The cut-in voltage is also found to decrease with increasing refractive index of the SIPOS (or decreasing oxygen content in the SIPOS). The reverse current was relatively temperature independence.

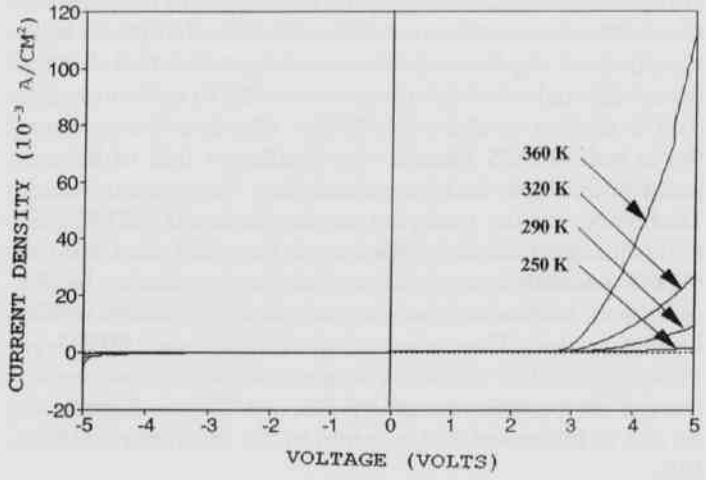

Fig. 5. Current density versus applied voltage with temperature as a parameter of a typical arsenic-implanted (1 x 10^{17} cm^{-2}) n+-SIPOS (R.I. = 1.8) on an n-type silicon isotype junction.

Figure 6 shows a semi-logarithmic plot of forward current density versus forward bias for the isotype junction of Fig. 5. A very distinctive "kink" is observed in the curves which defines two regions, one below the cut-in voltage and the other above. This "kink" becomes more pronounced as temperature increases. In the low field region, the rate of increase in current with increasing temperature is significantly smaller than the rate of increase in the high field region. Below the "kink" carrier tunneling through shallow traps at the interface is probably the dominant charge transport mechanism. Recombination at the interface is also expected owing to the presence of interface states at the junction. At higher electric fields, a temperature-activated charge transport is dominant. Hydrogen annealing of these devices passivated the shallow interfacial traps and eliminated the "kink" (Ranade et al., 1991).

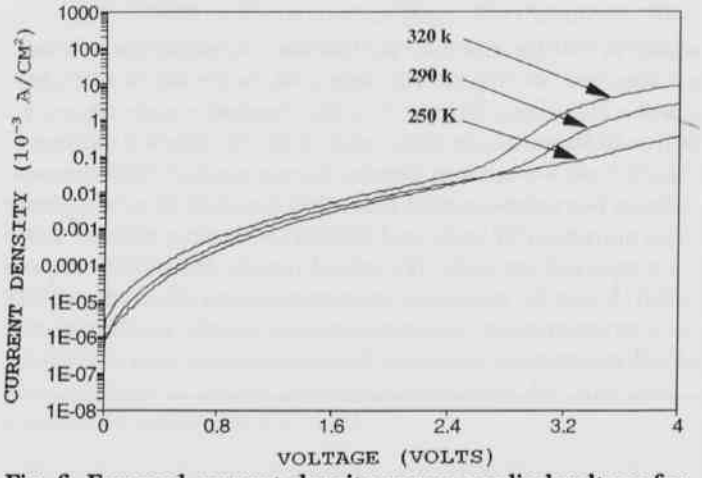

Fig. 6. Forward current density versus applied voltage for the isotype junction of Fig. 5.

Figure 7 shows the current density versus voltage characteristics as a function of temperature for a typical 1 X 10^{17} cm^{-2} arsenic-implanted SIPOS/n-Si isotype junction with a fluorinated SIPOS refractive index of 2.9. Characteristics similar to those of Fig. 5 are observed except that the current densities are approximately an order of magnitude higher. Also, the cut-in voltage at 290 K is about 0.9 V. Furthermore, the semi-logarithmic current density versus voltage characteristics of this structure does not exhibit a "kink" suggesting that the shallow interfacial traps are passivated during hydrolysis of the fluorinated SIPOS.

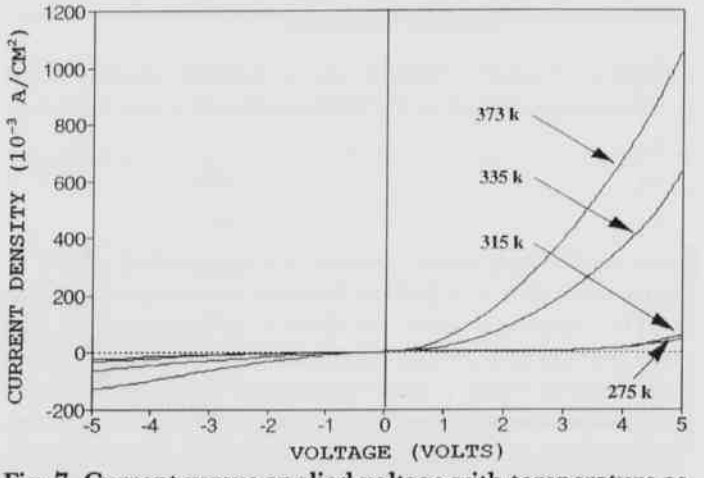

Fig. 7. Current versus applied voltage with temperature as a parameter for a typical arsenic-implanted (1 x 10^{17} cm^{-2}) n+-SIPOS (R.I. = 2.9) on an n-type silicon isotype junction.

In the reverse bias direction shown in Fig. 8, the current does not saturate with increasing bias, possibly because of space-charge induced lowering of the effective barrier height. The reverse current also increases slightly with increasing temperature, indicating a temperature-activated process. The unpassivated periphery could also contribute to this reverse current since the isotype junctions were not passivated intentionally in order to avoid any heat treatment after fabrication.

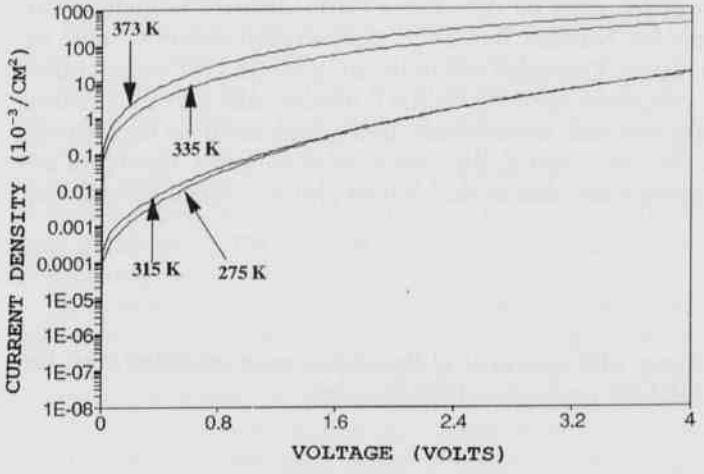

Fig. 8. Forward current density versus applied voltage for the isotype junction of Fig. 7.

Summary and Conclusions

Undoped SIPOS/p-Si heterojunctions were fabricated and electrically characterized. The J-V characteristics of these devices were compared to devices fabricated with fluorinated SIPOS. Carrier transport in these devices appears to be controlled by the SIPOS/p-Si interface. Fluorinated SIPOS heterojunctions exhibit a lower forward current density compared to un-fluorinated SIPOS heterojuntions. Furthermore, the reverse current of fluorinated devices saturates at relatively low applied bias.

The n+-SIPOS/n-Si isotype junction J-V characteristics were rectifying with a forward cut-in voltage of approximately 3 V, which decreases with both increasing temperature and refractive index of the SIPOS. The forward semi-logarithmic characteristics exhibit two distinct activation energies separated by a "kink". The low field conduction region is shown to result from shallow states at the n+-SIPOS/n-Si interface. The absence of the "kink" in the J-V characteristics of fluorinated n+-SIPOS/n-Si isotype junctions suggests that hydrogen species resulting from a hydrolysis process passivate the shallow interfacial traps.

Acknowledgements

The authors would like to express their appreciation to Dr. Tom Hill of Sandia National Laboratories, Albuquerque, NM, USA, and Dr. Joe Keenan of Texas Instruments Inc., Dallas, TX, USA, for their technical assistance. Part of this work was supported by the Arkansas Science and Technology Authority.

Literature Cited

Ang, S.S. 1988. IEEE Trans. Elect. Dev., Vol. ED-35, p. 1378.

Arnold, E. and **J.P. Karins.** 1983. Insulating films on semiconductors, Verweij, J.F. and Wolters, D.R., eds., p. 149.

Bolt, M.J.N. and **J.G. Simmons.** 1987. Solid-State Electron., Vol. 30, p. 553.

Lai, W.C., S.S. Ang, W.D. Brown., H.A. Naseem, R.K. Ulrich and **P.V. Dressendorfer,** 1990. J. Electron. Mater., Vol. 19, p. 419.

Matsushita, T., T. Aoki, H. Yamoto, H. Hayashi, M. Okayama and **Y. Kawana,** 1976. IEEE Trans. Elect. Dev., Vol. ED-23, p. 826.

Ong, P.H., S.S. Ang, W.D. Brown, H.A. Naseem, R.K. Ulrich and **P.V. Dressendorfer,** 1991. J. Electron. Mater., Vol. 20, p. 211.

Ranade, R.M., S.S. Ang, W.D. Brown, H.A. Naseem, J.R. Yeargan and **R.K. Ulrich,** 1991. Microelectronics Journal, Vol. 22, no. 7-8, p.47.

Sanchez, O., G. Gomez-Aleixandre and **C. Palacio,** 1993. J. Vac. Sci. and Technol. B., Vol. 11, p. 66.

Tarng, M.L. 1978. J. Appl. Phys., Vol. 49, p. 4069.

User-Interface Coding for the Cern/Geant Nuclear Physics Program

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Abstract

Explanations will be given of the various user-written routines required by the Monte Carlo detector-modeling program GEANT, developed by CERN, the European Organization for Nuclear Research. User-written routines must be linked with the CERN library to accomplish the researcher's intentions. Examples will illustrate how GEANT passes information to subprograms needed to model events. Various data structures used by GEANT library calls and included in each user routine, are similarly illustrated. Both computational-speed and memory-size limitations need to be factored into the construction of a simulation model. This will constrain the calls used in the user-written routines. Examples are provided of GEANT input data flags, defined by the user to determine simulation parameters and to control various testing choices in GEANT.

Introduction

Computing resources available to the majority of scientific users have increased dramatically in recent years. This has made it possible for most scientific users to start taking advantage of the more sophisticated and powerful software programs. An example of this type of program is the Monte Carlo event processor GEANT (Geant, 1992)–one of the most widely used by the high-energy and nuclear physics community. This program was developed by CERN, the European Organization for Nuclear Research in Geneva, Switzerland.

Until recently only large institutions with large programming staffs had sufficient computing power to run this type of program. As a consequence the GEANT user interface is quite complex and requires intricate, custom-coded user routines. To help new users, this paper will illustrate these user-subroutines, which are usually written in FORTRAN to take advantage of common data structures used by GEANT. (GEANT itself is written in FORTRAN.) Then these user-subroutines are linked with the rest of the GEANT package and run as a single unit.

GEANT code, relegated to the user, is concerned with several issues. These include the type and energy of each incoming particle, the shape and construction of the detector system, when to take in additional information and what information to output.

During 1992 the CERN program library was ported to a cluster of Digital Equipment DEC-5000 workstations at the University of Arkansas at Little Rock (UALR). Along with GEANT, other programs downloaded were HBOOK, ZEBRA, PAW, and PATHCY. These programs, along with a structural flowchart, were provided with the GEANT package to help the user.

Materials and Methods

Before the programs provided with the GEANT package were useful in our own simulations, many phone conversations with expert users were needed (Gagliardi, 1992; Prindle, 1992; Stancu, 1992; Throwe, 1992). This section communicates some of what was learned by our group, to provide beginning users a clearer picture of how to use these routines. A structural guide, summarizing the use of these routines, is included in the Results and Discussion section.

Memory size is the first concern to be addressed in the user-generated MAIN program. The user must set the size of dynamic memory in a call to GZEBRA. In order to minimize the swapping of code between memory and disk, the user should set the size of dynamic money close in value to the maximum real memory that is available. If the user runs out of memory during a simulation, decreasing the number of primary events tracked at once, which depends on the complexity of the primary events, is an option. Since the memory used to store data in each job is subsequently cleared after the processing of each group of primary events, simulation data in memory must be accommodated in some fashion (e.g., stored on disk) before going on to the next group of primary events.

UGINIT is the first user-subroutine called from the user-generated MAIN program. UGINIT sets up each run by reading in free format data records with a call to

GFFGO, which must be provided by the user. These input data records control the following processes: general run parameters (standard histograms, number of events, time); physical processes (Compton, Annihilation and other flags, energy cuts, minimum and maximum energy of cross sections); debug and I/O (events to debug, data structure names to save or print; user flags); user applications (flags, data areas); and other. Also, customized data records may be defined with each call to FFKEY.

GPART and GMATE are respectively called to set up tables for the standard particles and the standard materials. If custom material is used in the detector, GSMATE must be provided by the user and subsequently called to augment the call to GMATE. When using GEANT to simulate the response to new material compositions, calls to GSMATE can be made flexible with the use of customized data records (with calls to FFKEY). If this material is to be used in a detector, it must be made sensitive with a call to GSTMED with the ISVOL parameter set greater than zero.

To define detector geometry, the user must provide user-subroutine UIGEOM (subsequently calling it within UGINIT). This is done by providing sizes and shapes of the various volumes, made from simple geometric shapes: boxes, tubes, spheres, cones, etc. These may be placed side by side or inside each other to make complex composite shapes. A material number is assigned to each component volume separately. Any of these may be listed as sensitive volumes (in GSDET or GSDETV), indicating they are detectors not just structural material. Customized data records (with calls to FFKEY) may be used for greater flexibility, when using simulations to decide detector sizes or tuning proposed setups for detector shapes.

The MAIN program now calls the GRUN routine of GEANT. This sub-program controls the event and particle tracking until the end of the run. GRUN calls GTRIG, which in turn calls user-subroutine GUKINE, the initial kinematics setup. Calls within GUKINE to GSVERT describe each incoming beam particle's position, assigning a track number to each beam particle. Also within GUKINE, each call to GSKINE assigns a particle type and a momentum to each track number.

There are interfaces available to GEANT to access other Monte Carlo event generators to provide beam information, but calls to GSVERT and GSKINE are the easiest procedure when initially testing a detector. For example, when initially testing the response of silicon detectors to pions, user records (with calls to FFKEY) may be used to vary the incoming energy in assessing detector response. (Also, calls to FFKEY may be used to change particle type, to cross-check the predicted detector response with known plots.)

GTRIG next calls user-subroutine GUTREV. GUTREV usually consists of a call to GTREVE, followed by executing subsequent instructions within GUTREV for debugging and drawing tracks. The drawing part of GEANT has been left out of the discussion, due to the many differences in video libraries. However, drawing routines are not difficult and several examples are provided in the GEANT manual.

GTREVE takes over from GTRIG to do loop control. This consists of tracking the particles through the detector until they exit or decay. Secondaries may or may not be tracked according to the setup. GTREVE first calls user-subroutine GUTRAK which in turn calls GTRACK which subsequently calls user-subroutine GUSTEP.

GUSTEP is the main data-taking module. Here the user decides if something has happened. This is done by checking whether the index NGKINE is greater than zero. The user may then accumulate energy deposition, test particle types for decay, etc. Then the user can accept or reject particles for continued tracking. The user can also find out if particles have gone from one volume to another or how close they are to doing so. Also, the user may store the space points for subsequent plotting with GSXYZ.

GTRIG again takes over to call user-subroutine GUDIGI if it has been linked, but using program calls to HBOOK in the next user-subroutine GUOUT seems a much easier alternative. HBOOK files may be read by PAW, CERN's Physics Analysis Workstation program for detailed output (e.g., plots).

After user-subroutine GUOUT is finished, GRUN checks to see if all particles have been tracked to the limits of the detector. In that case, the user-generated MAIN program takes over and passes control to the user-subroutine UGLAST for final output and file closings.

Results and Discussion

Information about each current event is passed from one sub-program to another by using labeled-common data areas that can be accessed by user written code at anytime. Additional labeled-common areas may be constructed by the user if there are no naming conflicts. The important common areas and the data structures using them are indicated in the following tables. Table 1 and 2 summarize the authors experience with the common areas, the data structures and the subroutine calls within the program GEANT. Similarly, Table 3 illustrates the naming relationships among various calls to GEANT subroutines. These tables were constructed by the authors to illustrate the most important variables in GEANT.

Table 1. Module Structure of GEANT Subprograms

DEFINITIONS OF TERMS

ZEBRA - memory allocation monitor
event - particle has entered the detector
track - kinematics of the particle
step - user-defined distance along track before sampling
hit - interaction between particle and detector
[base, cons, geom, hits, kine, trak - GEANT manual sections]

PROGRAM SET-UP

MAIN user routine
GZEBRA initialize ZEBRA system, core allocation

INITIALIZATION

UGINIT user routine
base CALL FFKEY (Card, Variable, # of Variables, Type)
GINIT initialize variables
GFFGO interpret user run control records
GZINIT initialize ZEBRA core divisions and link areas
clears GCBANK common
GPART create JPART data structure
uses GPHYS common
GMATE create JMATE data structure
uses GCMATE common
UIGEOM user routine
cons CALLL GSMATE(#, Name, Parameters,...) uses JMATE
CALL GSTMET(#, Name, Material, Record Hit,...)
uses JTMED data structure
uses GCTMED common
geom CALL GSVOL(Name, Shape, Medium #<...)
uses GCVOLU common
CALL GSPOS(Name,..., Mother Volume, Position,...)
uses GCPUSH common
hits CALL GSDETV(Set for Detector, Volume,...)
creates JSET data structure
uses GCSETS common
CALL GSDETH(Set, Name,...)
phys GPHYSI prepares cross-section and energy loss tables
uses GCPHYS common

Table 2. Module Structure of GEANT (Continued)

RUN CONTROL

GRUN loops through events
GTRIG called by GEANT
kine GUKINE user routine controlling initial event kinematics
CALL GSVERT (Vertex Position, Track #,...)
create the JSVERTX data structure
uses GCKINE common
CALL GSKINE(Momentum, Particle, Vertex #,...)
create the JSKINE data structure
uses GCKINE common

EVENT PROCESSING

trak GUTREV user routine controlling looping through tracks
GTREVE loops through tracks - calls the following
GUTRAK user routine track control
GTRACK track control - calls the following
GUSWIM transports particle in steps
GUSTEP put hits → JHITS, put space
points → JXYZ, use GCTRAK common
NGKINE event happened? if yes then
CALL GSKING (Track #) put track and
particle info → GCKING common
CALL GSXYZ store space coordinates
GUSKIP user routine skips unwanted tracks

OUTPUT

base GUDIGI user routine setting digitization of data structures
hits CALL GSDIGI to create JDIGI data structure
[HBOOK has taken over much of GSDIGI's function]
base GUOUT is the user routine for output code
CALL GTRIGC to clear memory for the next event

TERMINATION

UGLAST the user termination routine
HBOOK CALL HISTDO to output stored histograms
base CALL GLAST for standard termination

Table 3. Data Name Relationships of GEANT Calls
[Arrows shows connnections between names]

GSPART (IPART particle #,...)
GSMATE (IMATE material #,...)
GSMIXT (IMATE,...)
↓
GSTMED (ITMED media #, NATMED name, NMAT material #)
↓
GSVOLU (NAME, SHAPE, NMED media #,...)
↑
GSPOS (NAME, NR copy # of name, MOTHER,...)
↓
GSDET (IUSET set identifier, IUDET name of volume,...)
↓ ↓
GSDETH (IUSET, IUDET,...)
↓ ↓
GSDIGI (ISET, IDET,...)

GSVERT(VERT see master reference system: MARS,...)
(see GSPART on 1st line)
↑
GSKINE(PLAB momentum components, IPART particle #,...)

GSKING(IT track #) stores all particle information by particle #
...their number NGKINE
...momentum GKIN
...time of flight TOFD + TOFG

Acknowledgements

This work acknowledges the help of colleagues in the Solenoidal Tracking experiment (STAR) at the Relativistic Heavy Ion Collider and colleagues in Experiment NA35 and Experiment NA49 at CERN. This work acknowledges the help of Charles Byrd and Christine Byrd in porting GEANT to the DEC-5000 workstations, and to Dr. Marcus D. Gabriel for help with the DEC-5000s. This work was supported in part by the U.S. Department of Energy and the Arkansas Science and Technology Authority.

Literature Cited

Gagliardi, S. 1992. Private Communication, CERN (Geneva, CH).

Geant 1992. Geant user's guide. CERN internal report. CERN Data Division, Geneva, CH. 3.15: 365 pp.

Prindle, D. 1992. Private Communication, University of Washington (Seattle, WA).

Stancu, I. 1992. Private Communication, Rice University (Houston, TX).

Throwe, T. 1992. Private Communication, Brookhaven National Laboratory (Upton, NY).

Arkansas Range Extensions of the Eastern Small-Footed Bat (*Myotis leibii*) and Northern Long-Eared Bat (*Myotis septentrionalis*) and Additional County Records for the Silver-Haired Bat (*Lasionycteris noctivagans*), Hoary Bat (*Lasiurus cinereus*), Southeastern Bat (*Myotis austroriparius*), and Rafinesque's Big-Eared Bat (*Plecotus rafinesquii*).

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Abstract

We continued field studies of bats in non-cave regions of Arkansas from 1989 to present and utilized specimens submitted to the Arkansas Department of Health Rabies Laboratory to establish Arkansas range extensions for the eastern small-footed bat (*Myotis leibii*) and northern long-eared bat (*Myotis septentrionalis*). In addition, we documented additional county records for the silver-haired bat (*Lasionycteris noctivagans*), hoary bat (*Lasiurus cinereus*), southeastern bat (*Myotis austroriparius*), and Rafinesque's big-eared bat (*Plecotus rafinesquii*).

Introduction

State range extensions and county records for plants and animals represent data that are vital in making informed decisions concerning land stewardship and are important in answering the questions of occurrence. In 1983 Heath et al., summarized a significant portion of the literature regarding bats in Arkansas and discussed state range extensions and county records for five species of vespertilionid bats. Since 1983 several additional studies (Fletcher et al., 1991; Heath et al., 1986; Heidt et al., 1987; Nelson et al., 1991; Saugey et al., 1988a; Saugey et al., 1988b; Saugey et al., 1989; Steward et al., 1986; Steward, 1988; Tumlison et al., 1992) have expanded our knowledge of the status, distribution, and occurrence of bats in Arkansas, particularly in the southern and southwestern areas of the state. A majority of these and previously published data were incorporated into *Arkansas Mammals* by Sealander and Heidt (1990). Records from all of these publications are included here.

Methods

Since 1989 our field research efforts were primarily concentrated in the non-cave regions of Arkansas. Double-framed harp traps and mist nets were employed at the entrances of abandoned mines and along closed roads and stream courses as described by Kunz (1988). Continued identification of specimens submitted to the Rabies Lab of the Arkansas Department of Health (ADHRL), begun in 1982, has proven to be an important resource and mechanism by which specimens are acquired statewide throughout the year. The ADHRL is especially important because many areas of Arkansas have not been adequately surveyed due to topography, land use patterns, and difficulty of using conventional capture equipment such as mist-nets and double-framed harp traps. In most cases vouchers were not retained for specimens submitted to the ADHRL due to the advanced state of deterioration of carcasses. In addition, voucher specimens for *Plecotus rafinesquii* were not retained for the Pope County record. Individuals captured were banded and released as part of a long term study of this species.

Results

Arkansas Range Extensions.--Myotis leibii. In Arkansas little is known of the natural history of the small-footed bat. This species has always been considered rare throughout the eastern portion of its range (Barbour and

Davis, 1969; Sealander and Heidt, 1990). Generally considered to be a cave bat, LaVal and LaVal (1980) believed this bat to be very rare in Missouri because the species was commonly captured in the western portion of its range but was virtually absent from Missouri caves and mines, and Caire (1986) observed the species was probably restricted to cave areas in southeastern Oklahoma. Caire (1986) and Stevenson (1986), and Saugey et al. (1989) examined a total of eleven specimens from Bear Den Caves in the Ouachita Mountains of LeFlore County, Oklahoma.

McDaniel et al. (1982) summarized the status of this species and its known occurrence within the Ozarks of southern Missouri and Arkansas listing 26 specimens. Twenty-three of these specimens were from four Arkansas counties: Independence (1), Newton (19), Searcy (1), and Stone (2). Sealander and Heidt (1990) reiterated the status of the species as described by McDaniel et al. (1982), and enlarged the area of distribution previously depicted by Sealander (1979) to reflect occurrence in the Springfield Plateau and Boston Mountain subdivisions of the Ozark Mountains. No additional information regarding distribution or habitat use in Arkansas has been published in the ensuing eleven years.

On 14 September 1992, a small-footed bat was collected in the city of Mena, Polk County. The specimen had been collected by a family's cat and was subsequently taken to a veterinary clinic and forwarded to the ADHRL where it was assigned ADHRL No. 358. The specimen tested negative for rabies and the carcass was frozen and retained for positive identification. The specimen was positively identified (DAS) and retained for deposition in the Collection of Recent Mammals at Arkansas State University. The male specimen was reproductively active as indicated by epididymides which extended into the uropatagium. Measurements were (millimeters): Total length = 85 mm; tail = 32 mm; foot = 7 mm; ear = 14 mm; tragus = 7.5 mm; left forearm (LFA) = 31 mm. The Mena location lies approximately 180 km southwest of the Newton County site and 55 km southeast of the Bear Den Cave site in LeFlore County, Oklahoma, and represents a significant range extension in Arkansas.

The occurrence of the small-footed bat in the Ouachita Mountains of Arkansas was unexpected because of distances to the nearest known caves. This bat is known to utilize caves, man-made structures, and trees during active periods of the year, but caves and mines are the only known winter habitat. Here they may be found in low ceiling passages, beneath stones, and within cracks in the cave floor. In portions of this bat's range, it is found to hibernate in drafty open mines and caves and hang very near entrances where the temperature drops below freezing and the humidity is very low. This species has a tolerance for cold, relatively dry places for hibernation (Krutzsch, 1966; Barbour and Davis, 1969; McDaniel et al., 1982). Interestingly, a specimen was discovered beneath a stone on a hillside while hunting for snakes in October, 1949, in Missouri (Barbour and Davis, 1969).

Considering the variety of unusual locations where this species has been encountered, it is possible this bat may utilize rock glaciers, also known as rock rivers, found on mountains composed of Jackfork Sandstone. Rich Mountain and Blackfork Mountain near Mena in Polk County, Arkansas, and in LeFlore County, Oklahoma, are composed of sandstone and harbor numerous rock glaciers (Foti, 1974). According to Charles Stone of the Arkansas Geological Commission (pers. comm.), these rock glaciers were probably formed in peri-glacial conditions (permanent snow fields during glacial epics). Some of these rock glaciers are 8-16 ha in size and are thought to attain depths of 15 m to bedrock. The insulating effect of these massive structures and the numerous openings which may lead to talus caves could provide suitable hibernating habitat for this bat in an area devoid of fracture or solutional caves. The small-footed bat is listed as a Category II federal candidate species by the U.S. Fish and Wildlife Service (USDI, 1991).

Myotis septentrionalis. The recent distribution of the northern long-eared bat suggested it was restricted to the Interior Highlands where it has been recorded in 14 counties: Baxter, Benton, Garland, Independence, Jackson, Marion, Montgomery, Newton, Pike, Polk, Scott, Stone, Washington, and Yell. However, two specimens received by the ADHRL suggest the range of this species may be more extensive than previously suspected.

On 4 September 1986 a male specimen (ADHRL #1228) was submitted for rabies examination from the city of Stuttgart, Arkansas County. Arkansas County lies within the Mississippi Alluvial Plain Natural Division (Shepherd, 1984). This locality represents a significant range extension of approximately 100 km from the nearest location in Jackson and Saline counties.

Another specimen submitted to the ADHRL (#1118) was a male captured on 24 June 1991 from the city of Benton, Saline County. The city of Benton lies within a transition zone between the Ouachita Mountain and West Gulf Coastal Plain natural divisions.

Several factors may have played roles in suggesting a restricted distribution in Arkansas. The absence of caves and mines in the West Gulf Coastal Plain and Mississippi Alluvial Plain natural divisions would have made capture of this gleaning species difficult. This bat is known to concentrate at such structures, particularly during fall breeding activities and hibernation. Lack of sampling and sparsely inhabited areas due to extensive agricultural, commercial and National Forest land-holdings, lessens the likelihood of human encounters. Also, the difficulty of netting or trapping this species, which is not highly

tied to riparian habitats for foraging where most mist-netting activities occur, may give a sense of scarcity or rarity. Saugey et al. (1989) encountered only 13 specimens in situations not associated with abandoned mines even though they extensively mist-netted streams and ponds during their study. Recently, harp-trapping and mist-netting at the entrances of abandoned mines during fall swarming activities have revealed this species rather common in the Ouachita Mountains (Saugey and Cochran, unpubl. data). Further investigations of areas currently not considered suitable habitat may indicate Hall's (1981) suggested statewide range for this species to be correct.

Additional County Records.--Lasionycteris noctivagans. The silver-haired bat has now been collected from all physiographic regions of the state and reported from the following eighteen counties; Baxter, Bradley, Columbia, Craighead, Garland, Greene, Howard, Independence, Jefferson, Little River, Pike, Polk, Pulaski, Saline, Scott, Sevier, Stone, and Washington. The "reliable sighting record" for Marion County, previously reported by Sealander (1979), was deleted by Sealander and Heidt (1990).

To this list we add Cleburne and Sharp counties from five specimens submitted to the ADHRL. All specimens from Cleburne County were males and reported from the city of Heber Springs. Their dates of capture and ADHRL Numbers are: 2 December 1983 (#1975); 8 November 1985 (#1465); 5 January 1990 (#570). Two specimens reported from Sharp County were a female captured on 30 December 1986 (#1653), and a male captured on 9 March 1987 (#196).

Lasiurus cinereus. The hoary bat had previously been reported from 23 counties: Ashley, Bradley, Craighead, Drew, Garland, Greene, Jefferson, Lawrence, Logan, Marion, Montogomery, Nevada, Newton, Polk, Pulaski, Saline, Scott, Sebastion, Stone, Washington, White, Woodruff, and Yell.

We have recorded two new county records as the result of specimens submitted to the ADHRL. A female (#1198) was captured on 29 April 1992 in Harrison, Boone County, and a male (#315) was captured in Texarkana, Miller County, on 22 September 1990. Distribution of these 25 records indicate state-wide occurrence as suggested by Sealander (1979) and Sealander and Heidt (1990).

Myotis austroriparius. The southeastern bat, a Category II federal candidate species, appears to be most abundant in the West Gulf Coastal Plain and Mississippi Alluvial Plain natural divisions. However, records in Garland (Davis et al., 1955) and Montgomery counties also place this species in the Central Ouachita Mountains subdivision in areas adjacent to major streams or impoundments. This species has been reported from the following fifteen counties: Bradley, Calhoun, Cleveland, Columbia, Drew, Garland, Grant, Howard, Independence, Little River, Miller, Ouachita, Pike, Sevier, and Woodruff. We have recorded this species from four additional counties: Lafayette, Mississippi, Montgomery, and Nevada.

The Montgomery County specimen was an adult male found hibernating in a small crevice in the ceiling of an abandoned mine near the Little Missouri River (T4S-R27W-S31) in February, 1991. The specimen weighed 7.5 g, had a LFA measurement of 37.5 mm, and was gray in color. This bat was retained as a voucher specimen for deposit in the Collection of Recent Mammals at Arkansas State University.

Specimens from Lafayette (T17S-R22W-S15; T17S-R22W-S10) and Nevada (T14S-R22W-S12) counties were captured from old water wells which had been hand-dug at the turn of the century. These wells measured, on average, 1 m in diameter and varied in depth up to 15 m. All wells in which this species was found were lined with concrete tiles or brick which provided a suitable roost substrate. When two or more bats occured within a well they typically formed a cluster. This was especially true with females but also occured when both sexes were present. When one bat roosted individually, even though a cluster was present, that bat typically was a male. This species has been found in wells at various times between September and March and apparently uses them primarily during the hibernation period. The largest number found at one time was 11 females. The well located in Nevada County has yielded southeastern bats on nine separate occasions over a 2-year period with a number of banded individuals recaptured. Numbers of bats observed have ranged from solitary individuals to a cluster of 11. Two wells in Lafayette County have yielded individual southeastern bats on a total of three occasions. Southeastern bats utilizing wells often share these refugia with *P. rafinesquii.* All specimens were banded and released.

The Mississippi County record was a female (#1028) submitted to the ADHRL on 5 June 1990.

Plecotus rafinesquii. Rafinesque's big-eared bat has previously been reported from Bradley, Calhoun, Clark, Cleveland, Columbia, Craighead, Crawford, Corss, Dallas, Drew, Faulkner, Grant, Greene, Jackson, Lafayette, Lawrence, Little River, Nevada, Ouachita, Pulaski, Sevier, and Union. We have recorded this species from Arkansas and Pope counties.

The Arkansas County site (T4S-R6W-S36) was located on Bayou Meto approximately 20 km south of the community of Humnoke. A maternity colony sporadically inhabited a 50-year old cypress barn that was entered daily in support of farm operations. According to local residents, Rafinesque's bats have used this barn since its completion (Monroe Williams, landowner, *pers. comm.*) The numbers of bats that used the roost varied dramati-

cally each time it was inspected with a single bat the least observed and the largest number having been approximately 175 individuals (females and nursing pups) present during the maternity period in June and July. Several hundred Rafinesque's bats have been banded and released as part of an ongoing life history investigation. Juvenile and adult voucher specimens have been deposited in the Collection of Recent Mammals at Arkansas State University.

The location for two Pope County records was an area of fractured sandstone containing fracture caves, substantial crevice openings, and talus caves in the bluffline above the Arkansas River at Russellville. The area is located just south of the Boston Mountains in the Arkansas Valley Natural Division which forms a transitional zone between the Ouachita and Ozark mountains (Shepherd, 1984).

On 27 January 1991, a non-scrotal, yearling Rafinesque's bat (born the previous spring) was found in torpor on an interior side-passage wall of Lands End Cave (T7N-R21W-S13). The specimen weighed 8.5 g, and had a LFA length of 43.4 mm. A yellow, split-ring plastic identification band (No. 824) was attached to the right forearm and the animal returned to the wall. The air temperature was 8.3° C and the relative humidity 95%. Twenty days later on 16 February 1991, Lands End Cave was examined but harbored no bats. Large cracks, crevices, and talus shelters within the sandstone bluff containing Lands End Cave were also examined. A solitary, adult, scrotal, Rafinesque's bat in deep torpor was observed roosting 2.5 m above the floor of a partially lighted talus cave. The specimen weighed 8.75 g and had a LFA length of 43.4 mm. A white, split-ring plastic identification band (No. 434) was placed on the right forearm and the bat returned to the original roosting site. The temperature at this location was 5° C and the relative humidity 45%.

Based on information garnered from research on this species in southern and eastern Arkansas, the presence of these bats, particularly the yearling, indicates a breeding population exists in the area (England and Saugey, unpubl. data).

Acknowledgements

Appreciation is expressed to L. Carolan, K. McNabb and C. Smith for valuable assistance in the field. Mrs. M. Edelman, Dr. T. C. McChesney, and Duc D. Vuong, DVM, of the Arkansas Department of Health, have been extremely helpful regarding specimens submitted to the Rabies Lab. This research was partially funded by a research grant from the Arkansas Nongame Preservation Committee (H. Grimmett, Chairman), a faculty research grant from Southern Arkansas University, and the United States Forest Service (Ouachita National Forest).

Literature Cited

Barbour, R.W. and **W.H. Davis.** 1969. Bats of America. Univ. Kentucky Press. Lexington. 286 pp.

Caire, W. 1986. Summer ecology of the bats of southeastern Oklahoma. Final Report to Oklahoma Department of Wildlife Conservation, Nongame Section. Oklahoma City. 22 pp.

Davis, W.H., W.Z. Lidicker, Jr. and **J.A. Sealander.** 1955. *Myotis austroriparius* in Arkansas. J. Mamm. 36:288.

Fletcher, O.D., J.D. Wilhide and **R.B. McAllister.** 1991. Observations on a resident population of *Myotis lucifugus*, in Jackson County, Arkansas. Proc. Ark. Acad. Sci. 45:123.

Foti, T.L. 1974. Natural divisions of Arkansas. Pp. 11-38, *In* Arkansas Natural Area Plan. Arkansas Department of Planning. Little Rock. 248 pp.

Hall, E.R. 1981. The mammals of North America. 2nd ed. 2 Vols. John Wiley and Sons, New York, N.Y. 1181 pp.

Heath, D.R., G.A. Heidt, D.A. Saugey and **V.R. McDaniel.**1983. Arkansas range extensions for the seminole bat (*Lasiurus seminolus*) and eastern big-eared bat (*Plecotus rafinesquii*), and additional county records for the hoary bat (*Lasiurus cinereus*), silver-haired bat (*Lasionycteris noctivagans*), and evening bat (*Nycticeius humeralis*). Proc. Ark. Acad. Sci. 37:90-91.

Heath, D.R., D.A. Saugey and **G.A. Heidt.** 1986. Abandoned mine fauna of the Ouachita Mountains, Arkansas: Vertebrate taxa. Proc. Ark. Acad. Sci. 40:31-36.

Heidt, G.A., D.A. Saugey and **S.R. Bradford-Luck.** 1987. Reported bat rabies in Arkansas. Proc. Ark. Acad. Sci. 41:105-107.

Krutzsch, P.H. 1966. Remarks on silver-haired and Leib's bats in eastern United States. J. Mamm. 47:121.

Kunz, T.H. 1988. Ecological and behavioral methods for the study of bats. Smithsonian Inst. Press, Washington, D.C. 533 pp.

LaVal, R.K. and **M.L. LaVal.** 1980. Ecological studies and management of Missouri bats with emphasis on cave-dwelling species. Terrestrial Series No. 8 Missouri Dept. Conserv. Jefferson City. 53 pp.

McDaniel, V.R., M.J. Harvey, R. Tumlison and **K.N. Paige.** 1982. Status of the small-footed bat, *Myotis leibii leibii,* in the southern Ozarks. Proc. Ark. Acad. Sci. 36:92-94.

Nelson, T.A., D.A. Saugey and **L.E. Carolan.** 1991. Range extension of the endangered gray bat, *Myotis grisescens*, into the Arkansas River Valley. Proc. Ark.

Journal of the Arkansas Academy of Science, Vol. 47 [1993], Art. 1

Acad. Sci. 45:129-131.

Saugey, D.A., D.G. Saugey, G.A. Heidt and **D.R. Heath.** 1988a. The bats of Hot Springs National Park. Proc. Ark. Acad. Sci. 42:81-83.

Saugey, D.A., G.A. Heidt, D.R. Heath, T.W. Steward, D.R. England and **V.R. McDaniel.** 1988b. Distribution and status of the Brazilian free-tail bat (*Tadarida brasiliensis cynocephala*) in Arkansas. Proc. Ark. Acad. Sci. 42:79-80.

Saugey, D.A., D.R. Heath and **G.A. Heidt.** 1989. The bats of the Ouachita Mountains. Proc. Ark. Acad. Sci. 43:71-77.

Sealander, J.A. 1979. A guide to Arkansas mammals. River Road Press, Conway. 313 pp.

Sealander, J.A. and **G.A. Heidt.** 1990. Arkansas mammals: Their natural history, classification, and distribution. Univ. Ark. Press. Fayetteville. 308 pp.

Shepherd, B. 1984. Arkansas's natural heritage. August House. Little Rock, AR 116 pp.

Stevenson, L.K. 1986. Some ecological aspects of *Myotis keenii* in Oklahoma. M.S. Thesis. Pittsburg State Univ., Pittsburg, KS. 61 pp.

Steward, T.W., V.R. McDaniel, D.A. Saugey and **D.R. England.** 1986. The bat fauna of southwest Arkansas. Proc. Ark. Acad. Sci. 40:72-73.

Steward, T.W. 1988. Distributions and habitat affinities of the mammals of southwest Arkansas. M.S. Thesis. Arkansas State Univ. 77 pp.

Tumlison, R., M. Karnes and **M. Clark.** 1992. New records of vertebrates in southwestern Arkansas. Proc. Ark. Acad. Sci. 46:109-111.

USDI - Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants: Animal candidate review for listing as endangered or threatened species; Proposed rule. Federal Register, 56(225):58804-58836.

Determination of Hammett Pyridine 3-Aza and 4-Aza Replacement Constants by ^{1}H NMR Studies of Amide Systems

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Abstract

Values for Hammett pyridine 3-aza and 4-aza replacement constants were obtained by correlation of the amide proton chemical shifts (in DMSO) of some N-(3-pyridyl)-and N-(4-pyridyl)-dichloronicotinamides, benzamides and acetamides with those of their N-(substituted phenyl) amide analogs using standard Hammett σ values.

Introduction

The concept of the role of the heteroatom as a "substituent" in the Hammett context has been the subject of much scrutiny (Exner, 1988). A primary consideration is that standard Hammett σ values are ultimately related to benzoic acid ionization data, and the absence of a heteroatom in benzoic acid provides sufficient variation in structure to render poor correlation. Indeed, one finds a large number of different values listed for a given heteroatomic "substituent" constant. These values, also known as σ replacement constant, vary in magnitude primarily because of the different methods employed to determine them, as well as secondary effects which may be attributed to the heteroatom. Consequently, numerous values have been reported for the pyridine 3-aza replacement constant ranging from 0.1 to 1.3, and reported 4-aza values span the range 0.6 to 1.6 (Charton, 1978). In this study we report values for the pyridine 3-aza and 4-aza replacement constants as determined from correlation of amide proton chemical shift data of N-pyridylamides with those of their N-substituted phenyl counterparts using standard Hammett σ values. Four different amide systems were studied.

Materials and Methods

Melting points were determined on a Mel-Temp II apparatus and are uncorrected. Elemental analyses were performed by Desert Analytics Organic Microanalysis Inc., Tucson, Arizona. Infrared spectra were obtained using a Perkin-Elmer model 1430 spectrophotometer equipped with a model 7300 data station, and samples were prepared as KBr disks. ^{1}H nmr spectra were determined on a Bruker AC-F 200 MHz superconducting FT spectrometer with deuterated DMSO as solvent and tetramethylsilane as the internal standard. Sample concentrations were approximately 0.1M. The known N-pyridylbenzamides **1c** and **2c** were prepared by the reaction of benzoyl chloride with 3-aminopyridine and 4-aminopyridine, and N-pyridylacetamides **1d** and **2d** were prepared by acetylation of 3- and 4-aminopyridine with acetic anhydride. N-(6-chloro-5-methyl-3-pyridyl) benzamide (**1g**) and N-(6-chloro-5-methyl-3-pyridyl) acetamide (**1h**) were synthesized as previously reported from our laboratory (Setliff, 1985). 2,6-Dichloronicotinic acid was obtained from Aldrich Chemical Co., Milwaukee, WI, and 5,6-dichloronicotinic acid was prepared as we have described previously (Setliff and Lane, 1976).

The following general procedure was employed for the preparation of new compounds **1a, 1b, 1e, 1f, 2a,** and **2b:** The appropriate dichloronicotinic acid (0.50g, 2.6 mmol) and thionyl chloride (3.0 ml) were combined and heated under reflux for 30 min. The resulting yellow transparent solution was subjected to vacuum evaporation to remove the excess thionyl chloride leaving the nicotinyl chloride as a viscous yellow oil. The oil was dissolved in dry ether (2 ml), and this solution was added slowly to a stirred solution of the appropriate aminopyridine (2.6 mmol) in dry pyridine (1.0 ml). This mixture was magnetically stirred under gentle reflux for 15 min, cooled, poured into ice water (100 ml), and the resulting suspension was vigorously stirred for 30 min. The crude amide was collected by filtration and recrystallized from either aqueous ethanol or water. Specific data for each compound are presented below.

N-(3-pyridyl)-2,6,-dichloronicotinamide(1a). This compound was obtained in 46% yield as light yellow crystals from aqueous ethanol. mp 126-127°C; ir: ν NH 3406 ν CO 1664 cm^{-1}; ^{1}H nmr: δ 10.96 (s, 1H), 8.83 (bs, 1H), 8.74 (d, J = 2Hz, 1H), 8.50 (d, J = 2Hz, 1H), 8.37 (d, J = 8Hz, 1H), 8.14 (d, J = 8Hz, 1H), 7.44 (m, 1H). *Anal.* Calcd for $C_{11}H_7N_3OCl_2$: C, 49.25; H, 2.61; N, 15.67. Found: C, 49.06; H, 2.66; N, 15.44.

N-(3-pyridyl)-5,6-dichloronicotinamide(1b). This com-

pound was obtained in 52% yield as white fluffy needles from aqueous ethanol. mp 188-189°C; ir: ν NH 3237, ν CO 1677 cm^{-1}; ^{1}H nmr: δ 10.76 (s, 1H), 8.91 (d, J = 2Hz, 1H), 8.89 (bs, 1H), 8.65 (d, J = 2Hz, 1H), 8.36 (bs 1H), 8.20 (d, 1H), 7.44 (m, 1H). *Anal.* Calcd for $C_{11}H_7N_3OCl_2$: C, 49.25; H, 2.61; N, 15.67. Found: C, 48.88; H, 2.72; N, 15.52.

N-(6-chloro-5-methyl-3-pyridyl)-2,6-dichloronicotinamide(1e). This compound was obtained in 73% yield as tan needles from aqueous ethanol. mp 215-216°C; ir: ν NH 3276, ν CO 1644 cm^{-1}; ^{1}H nmr: δ 11.02 (s, 1H), 8.51 (s, 1H), 8.23 (d, J = 8Hz, 1H), 8.12 (s, 1H), 7.78 (d, J = 8Hz, 1H), 2.36 (s, 3H). *Anal.* Calcd for $C^{12}H_8N_3OCl_3$: C, 45.50; H, 2.53; N, 13.27. Found: C, 45.68; H, 2.58; N, 13.12.

N-(6-chloro-5-methyl-3-pyridyl)-5,6-dichloronicotinamide(1f). This compound was obtained in 73% yield as tan needles from aqueous ethanol. mp 217-218°C; ir: ν NH 3277, ν CO, 1649 cm^{-1}; ^{1}H nmr: δ 10.79 (s, 1H), 8.89 (d, J = 2Hz, 1H), 8.62 (d, J = 2Hz, 1H), 8.59 (d, J = 2 Hz, 1H), 8.15 (d, J = 2Hz, 1H), 2.35 (s, 3H). *Anal.* Calcd for $C_{12}H_8N_3OCl_3$: C, 45.50; H, 2.53; N, 13.27. Found: C, 45.34; H, 2.54; N, 13.21.

N-(4-pyridyl)-2,6-dichloronicotinamide(2a). This compound was obtained in 86% yield as yellow fluffy needles from water. mp 150-151°C; ir: ν NH 3469, ν CO 1678 cm^{-1}; ^{1}H nmr: δ 11.09 (s, 1H), 8.52 (bs, 2H), 8.26 (d, J = 8Hz, 1H), 7.79 (d, J = 8Hz, 1H) 7.65 (bs, 2H). *Anal.* Calcd for $C_{11}H_7N_3OCl_2$: C, 49.25; H, 2.61; N, 15.67. Found: C, 49.07; H 2.59: N, 15.76.

N-(4-pyridyl)-5,6-dichloronicotinamide(2b). This compound was obtained as white fluffy needles from water. mp 195-196°C (with sublimation); ir: ν NH 3507, ν CO 1677 cm^{-1}; ^{1}H nmr: δ 10.87 (s, 1H), 8.90 (d, J = 2Hz, 1H), 8.63 (d, J = 2Hz, 1H), 8.53 (bs, 2H), 7.76 (bs, 2H). *Anal.* Calcd for $C_{11}H_7N_3OCl_2$: C, 49.25; H, 2.61; N, 15.67; Found: C, 49.23; H, 2.60; N, 15.50.

Results and Discussion

We reported the excellent correlation of the amide proton chemical shift (δ_{NH}, ppm in DMSO) of a series of N-(substituted phenyl)-2,6-dichloronicotinamides and N-(substituted phenyl)-5,6-dichloronicotinamides with standard Hammett σ constants for the substituents on the benzene ring (Setliff et. al., 1992) The respective correlation equations are:

(1) $\delta_{NH} = 0.70\sigma + 10.71$ (n = 8; $r^2 = 0.99$)

(2) $\delta_{nh} = 0.57\sigma + 10.56$ (n = 8; $r^2 = 0.99$)

Similarly, a series of N-(substituted phenyl) benzamides afforded the excellent correlation described by equation (3), (Soman, 1992).

(3) $\delta_{NH} = 0.64\sigma + 10.29$ (n = 8; $r^2 = 0.99$)

and a prior paper which examined a number of N-(substituted phenyl) acetamides (substituted acetanilides) in DMSO (Giffney and O'Connor, 1975) reported the correlation:

(4) $\delta_{NH} = 0.73\sigma + 9.93$ (n = 12; $r^2 = 0.99$)

To obtain a value for $\sigma_{3\text{-aza}}$ we prepared N- (3 pyridyl)-2,6-dichloronicotinamide (**1a**), - 5,6-dichloronicotinamide (**1b**), - benzamide (**1c**), and - acetamide (**1d**), measured their amide proton chemical shifts in DMSO, and subsequently substituted these values into the appropriate equation. The results are summarized in Table 1, Part A, and the values obtained for the four amide systems are reasonably consistent, with a mean of 0.34. Values for [$\sigma_{4\text{-aza}}$] were obtained in an analogous fashion by preparing the N-(4-pyridyl)- 2,6- and 5,6-dichloronicotinamides (**2a** and **2b**), - benzamide (**2c**), and - acetamide (**2d**). The results are presented in Table 1, Part C, and an average value of 0.55 was calculated from the fairly consistent results derived from the four amide systems. It is interesting, although not particularly significant, that these values agree best with those previously determined from infrared measurements. Joeckle and coworkers reported $\sigma_{3\text{-aza}}$ as 0.33 and $\sigma_{4\text{-aza}}$ as 0.62 by correlation of the intensities of the methyl C-H and amino N-H stretching modes of 3- and 4-methylpyridine and 3- and 4-aminopyridine with a series of ring substituted toluenes and anilines (Joeckle et al., 1966).

In order to determine if our $\sigma_{3\text{-aza}}$ value of 0.34 would operate predictably in concert with standard Hammett σ values in the systems studied herein, we prepared compounds **1e** through **1h** and measured the amide proton chemical shifts. Using the $\sigma_{3\text{-aza}}$ value of 0.34 together with the standard Hammett values (Exner, 1988) of 0.22 for $\sigma_{4\text{-chloro}}$ and -0.06 for $\sigma_{3\text{-methyl}}$, an additive σ value of 0.50 was obtained. When this additive value is substituted into four correlation equations, the δ_{NH} thus calculated compares favorably with the observed values in the four amide systems. The results are summarized in Table 1, Part B.

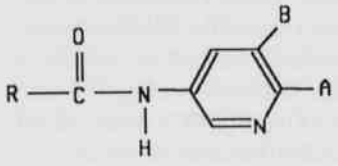
At this point it is appropriate to mention that an earlier report (Katritsky and Swinbourne, 1967), which described ^{1}H nmr studies of ring substituted β-phenylacrylic acids in DMSO, exhibits a good linear correlation of the α-vinylic proton chemical shift with standard Hammett σ values. From the chemical shifts of the corresponding β-(3-pyridyl)- and β-(4-pyridyl) acrylic acids, 3-aza and 4-aza replacement constants of 0.6 and 0.8 were graphically determined. No correlation equation was presented, but on analysis of these data we derived the equation shown as (5):

(5) δ_{α}-vinylic = 0.32σ + 6.49 (n = 8; r^2 = 0.97)

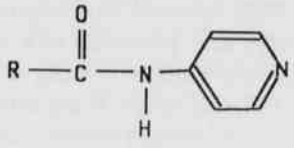
The rather small coefficient of σ indicates a comparatively weaker response of the vinylic proton to the transmission of electronic effects than the amide proton in our systems. The enhanced sensitivity in the amide systems is undoubtedly related to the large amount of hydrogen bonding of the amide proton to the DMSO solvent, which in turn renders the amido nitrogen sufficiently negative and therefore quite responsive to electronic effects. The larger aza replacement values generated from the acrylic acid data are obviously not explainable in terms of hydrogen bonding of the vinylic proton itself, but possibly could be explained in terms of secondary effects resulting from hydrogen bonding of the acid proton.

In conclusion, it appears that the pyridine 3-aza and 4-aza values reported herein are valid for correlation studies involving the hydrogen bonded amide proton in DMSO. As in all previously reported cases, (Charton, 1978) our results also demonstrate a larger value for [$\sigma_{4\text{-aza}}$] owing to mesomeric as well as inductive effects which are operative in the 4- position.

Table 1. Correlation Data for the N-(pyridyl)amide Systems



1



2

Cpd.	R	A	B	Obs. δ_{NH}	Correl. Eq/ No.	$\sigma_{3\text{-aza}}$[a]	Calc.[b] δ_{NH}
A.							
1a	2,3-diCl-3-pyridyl	H	H	10.96	1	0.37	---
1b	5,6-diCl-3-pyridyl	H	H	10.76	2	0.35	---
1c	phenyl	H	H	10.49	3	0.31	---
1d	methyl	H	H	10.17	4	0.34	---
B.							
1e	2,6-diCl-3-pyridyl	Cl	CH_3	11.02	1	---	11.06
1f	5,6-diCl-3-pyridyl	Cl	CH_3	10.80	2	---	10.84
1g	phenyl	Cl	CH_3	10.55	3	---	10.61
1h	methyl	Cl	CH_3	10.39	4	---	10.30
C.						$\sigma_{4\text{-aza}}$[c]	
2a	2,6-diCl-3-pyridyl	–	–	11.09	1	0.56	---
2b	5,6-diCl-3-pyridyl	–	–	10.87	2	0.56	---
2c	phenyl	–	–	10.63	3	0.53	---
2d	methyl	–	–	10.34	4	0.55	---

[a]mean value is 0.34 [b]σadditive = (0.34 + $\sigma_{4\text{-Cl}}$ + $\sigma_{3\text{-Me}}$) [c]mean value 0.55

Acknowledgements

This work was supported in part by a grant form the University of Arkansas at Little Rock Faculty Research Fund. The authors wish to thank Mrs. Robbin Long for computer assistance in the determination of the correlation equations.

Literature Cited

Charton, M. 1978. Heteroaromatic replacement con stants. Pp. 233-236, *In* Correlation analysis in chemistry, (N.B. Chapman and J. Shorter, eds.) Plenum Press, New York 465 pp.

Exner, O. 1988. Correlation analysis of chemical data. pp. 133-135. Plenum Press, New York, 275 pp.

Giffney, C.J. and **C.J. O'Conor.** 1975. Substituent effects on the nmr spectra of substituted acetanilides and phenylureas. J. Magn. Res. 18:230-234.

Joeckle, R., E.D. Schmid, and **R. Mecke.**1966. Untersuchungen der IR gruppenintensitaten eniger monosubstituierter pyridin und benzolderivate. Z. Naturforsch. 21A:1906-1907.

Katritsky, A.R. and **F.J. Swinbourne,** 1967. Applications of proton resonance spectroscopy to structural problems. Determination of Hammett sigma constants for heterocycles. J. Chem. Soc. 6707-6710.

Setliff, F.L. 1985. New haloacetamido and benzamidomethyl pyridines. Org. Prep. Proc. Int. 17:68-69.

Setliff, F.L., and **J.E. Lane.** 1976. Some 2,5- and 5,6- dihalo nicotinic acids and their precursors. part IV. J. Chem. Eng. Data 21:246-247.

Setliff, F.L., N.G. Soman, J.Z. Caldwell and **D.L. Rogers.** 1992. Hammett correlations in the proton nmr spectra of some N-aryldihalonicotinamides. Proc. AR. Acad. Sci. 46:72-74.

Soman, N.G. 1992. Studies on the preparation and properties of some 2,6- and 5,6- dichloronicotinic acids. Unpublished M.S. Thesis, University of Arkansas at Little Rock, 106 pp.

The Prevalence of *Borrelia burgdorferi*, the Lyme Disease Spirochete, in Ticks and Rodents in Northeast Arkansas

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Abstract

Lyme disease, caused by the spirochete, *Borrelia burgdorferi*, has been reported from 36 of Arkansas' 75 counties. Ticks and wild rodents from nine northeast Arkansas counties were surveyed to determine the prevalence of *Borrelia* infection in potenial tick vectors and reservoir host populations. Indirect immunofluorescent assays with murine monoclonal antibody H5332, specific for *B. burgdorferi*, detected a 2.1% rate of infection for the 638 ticks surveyed and an 11.8% infectivity rate for the 102 rodents surveyed.

Introduction

Lyme disease is a tick-borne bacterial infection that was initially identified in the mid-1970's as a form of juvenile arthritis (Steere et al., 1977). The etiologic agent is a spirochete, *Borrelia burgdorferi*, first isolated in 1982 by Burgdorfer et al. (1982). Humans most often acquire the disease when bitten by an infected vector.

The incidence of Lyme disease is difficult to estimate because of variability among states in reporting requirements, case definitions, and surveilance methods (Cielsielski et al., 1988). Nevertheless, Lyme disease is considered to be the most commonly reported vector-borne disease in the United States (Miller et al., 1990). In Arkansas 99 cases of Lyme disease have been reported from 1988 to 1992 (T. McChesney, 1993, pers. comm.).

Epidemiological evidence suggests that the Lyme spirochete is maintained in the wildlife population by reservoir hosts and infected overwintering vectors. Through either bacterial isolation or serological surveys, this organism has been associated with a wide variety of wild and domestic animals including white-footed mice, chipmunks, raccoons, skunks, squirrels, ground-feeding birds, rabbits, white-tailed deer, horses, cows, dogs, and cats (Anderson et al., 1983; Anderson and Magnarelli, 1984; Anderson et al., 1985).

The pattern of spirochete transmission appears to involve larval or nymphal ticks acquiring the spirochete by feeding on an infected reservoir host. This infection is carried through to either the nymph or adult stage (transstadial passage) which, while feeding, infects the next host. Humans typically acquire the infection when fed upon by infected nymphs.

The transmission cycle is most clearly understood in the Northeast because of the concentration of research conducted there. In this endemic Lyme-disease region, *Ixodes dammini*, the deer tick, is the principal vector implicated in the cycle and *Peromyscus leucopus*, the white-footed mouse, is considered the major reservoir host (Burgdorfer et al., 1982; Burgdorfer, 1984; Anderson et al., 1985; Spielman et al., 1985). The infectivity rate for these mice has been as high as 86% in endemic foci (Anderson et al., 1985). A natural infection rate of 35% has been reported for the deer tick in this area (Anderson et al., 1983; Magnarelli and Anderson, 1988).

Although the epidemiological picture for Lyme diseae is well-constructed in the Northeast, little is known about its status in the South where there is an increasing incidence (Burgdorfer and Gage, 1987; Cielsielski et al., 1988). Several investigations into possible wildlife reservoirs and potential tick vectors have helped to initiate a better understanding of Lyme disease ecology in the southern states. Burgdorfer and Gage (1987) determined that the hispid cotton rat, *Sigmodon hispidus*, is capable of developing a *Borrelia burgdorferi* infection and, when spirochetemic, can be infective for the nymphs of feeding *Ixodes scapularis*, the black-legged tick. They further observed that this tick is also capable of transmitting the spirochete. Two other species of ticks, *Amblyomma americanum*, the lone star tick, and *Dermacentor variabilis*, the American dog tick, have been found to be naturally infected (Schulze et al., 1984; Anderson et al., 1987; Magnarelli and Anderson, 1988; Feir and Reppel, 1990). All three of these tick species are found in abundance in Arkansas.

The purpose of this study was to address three main questions relevant to the epidemiology of Lyme disease in northeast Arkansas: (1) What tick(s) potentially serve(s) as vector(s) for *B. burgdorferi*?; (2) What is the prevalence of *B. burgdorferi* in the potential tick vector population(s)?; and (3) What is the prevalence of *B. burgdorferi* infection in potential wild rodent reservoirs? Such information should help in the construction of an epidemiological picture for Lyme disease in this area. Identification of the most commonly encountered vector(s) could be useful in defining seasonal and locational

risk factors. Estimation of the prevalence of *Borrelia* infection in both potential reservoir hosts and arthropod vectors is necessary to accurately asses the threat that Lyme disease poses to people living within the study area.

Material and Methods

Collection and Examination of Ticks.--The ticks examined in this study were collected from several locations in Clay, Craighead, Fulton, Greene, Izard, Lawrence, Poinsett, Randolph, and Sharp counties in northeast Arkansas. Specimens were obtained either by removal from their mammalian hosts within a study site or by flagging vegetation in the various study areas. Collected ticks were placed in bags containing a moist paper towel until they could be examined in the laboratory. Ticks were identified to species, sex, and developmental stage.

After identification, the internal body content of each tick was dissected and smeared in a drop of phosphate-buffered saline on a ten-well, teflon-coated glass slide. This film was examined by darkfield microscopy. Those slides on which spirochetes were detected were air-dried, fixed in methanol, and examined by indirect immunofluorescence. Murine monoclonal antibody (mAb) H5332, prepared against *Borrelia burgdorferi*, (compliments of Dr. Alan G. Barbour, University of Texas Health Sciences Center, San Antonio, TX) and fluorescein isothiocyanate-labeled goat anti-mouse immunoglobulin G (IgG) were used in the indirect fluorescent-antibody (IFA) staining (Anderson and Magnarelli, 1984).

Isolation and Cultivation of* Borrelia *from Feral Rodents.--Rodents were collected either by Museum Special snap traps or by Sherman box traps (H. B. Sherman Co., Deland, FL) from Clay, Craighead, Fulton, Greene, Lawrence, Poinsett, Randolph, and Sharp counties in northeast Arkansas. Those animals captured in box traps were euthanized with chloroform. All specimens were identified as to species and prepared for necropsy by removal of abdominal hair with a depilatory. After hair removal, the animals were placed in a 5.25% sodium hypochlorite solution for three minutes, rinsed with sterile water, and painted with an iodine-alchol mixture to minimize microbial contamination.

BSK-II medium (Barbour, 1984; Berger et al., 1985; Barbour, 1986) was used for bacterial cultivation. After preparation, the medium was filter sterilized through a 0.22 micron filter and dispensed into sterile, screw-up culture tubes. After the animals were prepared for necropsy, the spleen and urinary bladder were aseptically removed and triturated in 2 ml of BSK-II medium with a sterile Dounce homogenizer. A 1 ml portion of this extract was inoculated into a sterile culture tube containing BSK-II medium. The tubes were incubated at 34°C for 6-8 weeks. Based on previous work (Anderson et al., 1985; Anderson et al., 1987; Schwann et al., 1988), each culture was examined weekly for spirochetes by darkfield microcopy for the first 3 weeks and periodically thereafter.

Results

Tick Data.--A total of 638 ticks from a nine-county area (Fig. 1) was collected from fall 1989 through fall 1991 and examined for *Borrelia burgdorferi*. Four different species were represented in this total as were both sexes and two life cycle stages (Table 1). Of the ticks collected and examined, 13 (2.08%) contained spirochetes which reacted positively with murine mAb H5332 specific for *Borrelia burgdorferi* (Table 1). *Amblyomma americanum* and *Ixodes scapularis* were the two tick species most commonly encountered in both the general and the *Borrelia*-infected tick population (Table 1). Geographically, tick specimens exhibiting a positive antibody reaction were found in only four of the nine counties surveyed (Fig. 1).

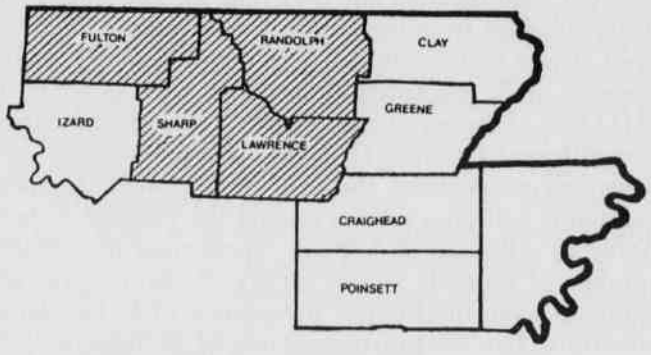

Fig. 1. Northeast Arkansas counties included in the tick survey. (Counties in which infected ticks were collected are cross-hatched).

Table 1. Comparison of the general tick population with the *Borrelia*-infected tick population for ticks collected from northeast Arkansas from fall 1989 throught fall 1991.

Species	Sex	Stage	Total Infected	Total
Amblyomma americanum (lone star tick)	5/132 f	2/55 n	7	200
	2/68 m	5/145 a		
Dermacentro variabilis (American dog tick)	0/101 f	0/6 n	1	180
	1/79 m	1/174 a		
Ixodes scapularis (black-legged tick)	0/126 f	0/0 n	5	225
	5/99 m	5/225 a		
Rhipcephalus sanguineus (brown dog tick)	0/15 f	0/17 n	0	21
	0/6 m	0/4 a		
	5/374 f	2/78 n	13	626
	8/252 m	11/548 a		

KEY: f = female; m = male; n = nymph; a = adult

Rodent Data.--A total of 102 rodent specimens, representing 10 species, was collected in an eight-county area from fall 1989 through fall 1991 (Fig. 2). The spleen and urinary bladder from each animal were removed and cultured. These tissue cultures were then examined for the presence of *B. burgdorferi*. Spirochetes were observed in 12 (11.8%) of these cultures. These 12 animals came from four different counties (Fig. 2). *Sigmodon hispidus* and *Peromyscus maniculatus*, the deer mouse, were the most-commonly collected species among the infected rodents (Table 2). Although *S. hispidus* represented the greatest number of animals in the survey, *P. maniculatus* was found to have the highest prevalence of *B. burgdorferi* infection. The overall prevalence of *Borrelia*-infected rodents from Randolph, Craighead, Greene, and Poinsett counties was 18.8%, 16%, 14.3%, and 5.5% respectively.

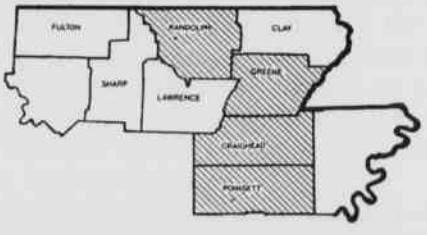

Fig. 2. Northeast Arkansas counties included in the rodent survey. (Counties in which infected rodents were collected are cross-hatched.)

Table 2. Rodent species and numbers collected from northeast Arkansas from fall 1989 through fall 1991 and examined for *B. burgdorferi* infection.

Species	No. infected	No. total	%
Microtus pinetorum (Woodland vole)	0	7	0.0
Mus musculus (House mouse)	0	19	0.0
Neotoma floridana (Eastern wood rat)	0	1	0.0
Oryzomys palustris (Marsh rice rate)	1	5	20.0
Peromyscus gossypinus (Cotton mouse)	1	9	11.1
Peromyscus leucopus (White-footed mouse)	1	9	11.1
Peromyscus maniculatus (Deer mouse)	5	15	33.3
Reithrodontomys fulvescens (Fulvous harvest mouse)	0	2	0.0
Sigmodon hispidus (Hispid cotton rat)	4	33	12.1
Tamias striatus (Eastern chipmunk)	0	1	0.0
unknown	0	1	0.0
TOTAL	12	102	11.8

Discussion

Since 1988, 36 of Arkansas' 75 counties have reported a total of 99 cases of Lyme disease. Of the nine counties included in this survey, five (Craighead, Greene, Poinsett, Sharp, Randolph) have reported at least one case of Lyme disease within the last six years. In this study, either tick midgut smears or rodent tissue cultures which reacted positively with mAb H5332 were detected from all five counties in which Lyme disease has been reported (Figs. 1 and 2). Additionally, three positive ticks were found in two counties (Fulton and Lawrence) where no human cases of Lyme disease have yet been reported. These findings help substantiate the clinical diagnosis of Lyme disease since they provided evidence of the presence of both the etiologic agent and infected tick vectors.

Ixodes scapularis has been proposed as the potential major vector in the southeast U.S. because of its relationship to the major vector in the Northeast, *I. dammini*, and its proven vectorial capacity in the laboratory (Burgdorfer and Gage, 1987; Piesman and Sinsky, 1988). Natural infection rates of *I. scapularis* have been quite low (<1%) as compared to the natural infection rates for *I. dammini*

which have been as high as 35% (Anderson et al., 1983; Magnarelli et al., 1986; Magnarelli and Anderson, 1988; Piesman and Sinsky, 1988). Recent evidence, however, suggests that *I. scapularis* and *I. dammini* are not distinct species and should not be separated as such (Oliver et al., 1993). If this is true, then the importance of *I. scapularis* cannot be understated despite the differences in the reported prevalence of *Borrelia* infection. It is possible that the variation in the natural infection rates between these two ticks is due more to reservoir host infection rates than to differences in vectorial capacity.

In this study, 2.2% of the *I. scapularis* were determined to react positively upon IFA analysis. All of these ticks were adults and were obtained form white-tailed deer. Since all the positive black-legged ticks in this investigation were attached to an animal host at collection, it was impossible to determine if the ticks were infected prior to feeding or if the ticks ingested the bacteria while feeding on a spirochetemic host. The former case suggests acquisition of the infection as a nymph with subsequent transstadial passage and implies a potential ability of the tick to transmit the organism to another host. The latter scenario neither supports nor refutes vectorial capacity.

Evidence gathered in this study also suggests another important vector for Lyme disease in northeast Arkansas, *Amblyomma americanum*. The lone star tick showed the greatest infectivity rate, 3.5%, of the ticks examined. Feir and Reppell (1990) reported a similar infection rate (2.3%) for this tick in Missouri. Other populations of naturally-infected *A. americanum* in Alabama, North Carolina, and New Jersey have also been found (Schulze et al., 1984; Magnarelli et al., 1966; 1991). However, the efficiency of *Amblyomma* as a vector for *Borrelia burgdorferi* has been questioned. Piesman and Sinsky (1988) reported that the capacity of the lone star tick to acquire *Borrelia* infection varied among populations. They further noted that if infection was established, the organisms were lost in transstadial passage.

Conversely, the lone star tick has been strongly associated with the development of an erythema migrans rash in a number of Lyme disease cases diagnosed at a family clinic in Cape Griardeau, Missouri (Masters, 1990). In every instance immunological testing confirmed the diagnosis of Lyme disease. Outside of the southern U.S., *Amblyomma* has been implicated as a potential vector in New Jersey (Schulze et al., 1984).

In this investigation both nymphs and adults of *A. americanum* were found to be infected with *Borrelia* (Table 1) and the majority of these were collected from flagging vegetation. Similarly, Schulze et al. (1984) also reported spirochetes from both nymphs (22%) and adults (5.8%) of this species. A major question raised by the positive ticks swept from vegetation concerns the time their infection was acquired. One possibility is that the ticks were infected with the spirochete as larvae or nymphs and the infection was passed transstadially into the respective nymphs or adults. Piesman and Sinsky (1988) reported that transstadial passage of *Borrelia burgdorferi* in *A. americanum* was non-existent in the metamorphosis from larva to nymph. Published information was not found documenting the success of transstadial passage from nymph to adult in the lone star tick. It is feasible that, even if the spirochete can not be transstadially passed from larva to nymph, a passage from nymph to adult is possible. Another likely explanation for infection within a given stage is that the infection may have been acquired in that stage, and the ticks simply have not yet molted. In the first situation, an infected tick could serve as a vector for a new host. In the latter scenario, the vectorial capacity of a tick lies in its ability to transstadially pass the spirochete since the tick has already fed.

In addition to the lack of evidence supporting transstadial passage of *B. burgdorferi* in *Amblyomma*, there have been no published reports of the successful transmission of *Borrelia burgdorferi* to a host by infected *A. americanum* ticks within the confines of a laboratory setting. Until these relationships can be conclusively established, the vectorial capacity of *A. americanum* for the Lyme disease spirochete can only be hypothesized.

One other potential tick vector in northeast Arkansas is *Dermacentor variabilis*, the American dog tick. Examination of 180 *D. variabilis* ticks yielded one (0.55%) positive adult male. Naturally-occuring infection rates of 1.3% have been reported for the American dog tick in Missouri (Feir and Reppell, 1990). Other populations of *Borrelia*-infected nymphs and larvae have been reported from the eastern U.S. (Anderson et al., 1985; Anderson et al., 1987; Magnarelli and Anderson, 1988). However, at this time there is no convincing published evidence linking the bite of *D. variabilis* to the development of an EM rash in humans nor have any known laboratory experiments demonstrated the American dog tick to transmit the Lyme spirochete to a specific host.

This investigation does not address the actual effectiveness of any given tick species as a vector of Borrelia burgdorferi to humans. Rather, this study was designed to clarify which tick(s) could serve as Borrelia vectors in northeast Arkansas and to determine the extent of infection in the tick population. The data gathered suggest that *Amblyomma americanum* and *Ixodes scapularis* are the most likely candidates for Lyme vectors.

Another key aspect of the Lyme disease epidemiological picture in northeast Arkansas is the maintenance of the spirochete in reservoir host populations. These hosts serve as overwintering agents for *B. burgdorferi* and as reservoirs of infection for feeding tick vectors (Anderson et al., 1987). Isolation of spirochetes from feral rodents

burgdorferi, Arkansas Academy of Science, Vol. 47, 1993, Art. 1

has been suggested as a method for identifying endemic areas of Lyme disease (Anderson et al., 1985). Burgdorfer and Gage (1987) determined that the hispid cotton rat, *Sigmodon hispidus,* was a competent reservoir for the spirochete and suggested field studies of wild rodents to further elucidate the ecology of *Borrelia burgdorferi* in the South.

In the present investigation, an 11.8% infectivity rate was noted among the 102 rodents examined. The Lyme disease organism was cultured from the following five species of the 10 different species studied: *Oryzomys palustris* (the marsh rice rat), 20%; *Peromyscus gossypinus* (the cotton mouse), 11.1%; *Peromyscus leucopus* (the white-footed mouse), 11.1%; *Peromyscus maniculatus* (the deer mouse), 33.3%; and *Sigmodon hispidus* (the cotton rat), 12.1%. These infection rates correlate with results from a similar survey conducted across North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi by Magnarelli et al. (1992). These investigators found infection rates for *P. gossypinus* of 21.7%, 37.9%, 35.0%, 15%, and 17.3%, respectively, for the aforementioned states. Additionally, 30% of *P. leucopus* examined from North Carolina possessed antibodies to *B. burgdorferi.*

All of the *Borrelia*-positive rodents were identified from counties where human cases of Lyme disease have been reported. The relative importance of any particular rodent species as a *Borrelia* reservoir goes beyond the scope of this project. It is evident that *Borrelia burgdorferi*, or a closely-related spirochete, exists in both potential tick vectors and reservoir host populations in northeast Arkansas. Further investigations should include an intensive study of identified tick vectors followed by feral rodent surveys in those areas where positive vectors have been recovered.

Acknowledgements

We would like to thank Dr. Alan Barbour, University of Health Sciences Center, San Antonio, TX, for his gift of murine monoclonal antibody H5332 for the IFA staining. We would also like to thank Dr. Tom Schwann for the reference strains of *B. burgdorferi* used in preliminary work and for his insightful suggestions into spirochete culture. We are indebted to Dr. V. R. McDaniel and J. D. Wilhide for their assistance in identifying rodents and for helpful trapping techniques. Our appreciation is also extended to J. D. Wilhide for his assistance with the compilation of a data base. We want to extend our appreciation to the Arkansas Department of Health for their generous financial support of this project.

Literature Cited

Anderson, J.F., R.C. Johnson and **L.A. Magnarelli.** 1987. Seasonal prevalence of *Borrelia burgdorferi* in natural populations of white-footed mice, *Peromyscus leucopus*. J. Clin. Micro. 25(8):1564-1566.

Anderson, J.F., R.C. Johnson, L.A. Magnarelli and **F.W. Hyde.** 1985. Identification of endemic foci of Lyme disease: isolation of *Borrelia burgdorferi* from feral rodents and ticks (*Dermacentor variabilis*). J. Clin. Micro. 22(1):36-38.

Anderson, J.F. and **L.A. Magnarelli.**1984. Avian and mammalian hosts for spirochete-infected ticks and insects in a Lyme disease focus in Connecticut. Yale J. Biol. Med. 57:627-641.

Anderson, J.F., L.A. Magnarelli, W. Burgdorfer and **A.G. Barbour.** 1983. Spirochetes in *Ixodes dammini* and mammals from Connecticut. Am. J. Trop. Med. Hyg. 32(4):818-824.

Barbour, A.G. 1984. Isolation and cultivation of Lyme disease spirochetes. Yale J. Biol. Med. 57:521-525.

Barbour, A.G. 1986. Cultivation of *Borrelia*: a historical overview. Zentralbl. Bakt. Mikr. Hyg. A263:11-14.

Berger, B.W., M.H. Kaplan, I.R. Rothenberg and **A.G. Barbour.** 1985. Isolation and characterization of the Lyme disease spirochete from the skin of patients with erythema chronicum migrans. J. Am. Acad. Dermatol. 13:444-449.

Burgdorfer, W. 1984. Discovery of the Lyme disease spirochete and its relation to tick vectors. Yale J. Biol. Med. 57:515-520.

Burgdorfer, W., A.G. Barbour, S.F. Hayes, J.L. Benach, E. Grunwaldt and **J.P. Davis.** 1982. Lyme disease–a tick-bone spirochetosis? Science 216:1317-1319.

Burgdorfer, W. and **K.L. Gage.** 1987. Suseptibility of the hispid cotton rat (*Sigmodon hispidus*) to the Lyme disease spirochete (*Borrelia burgdorferi*). Am. J. Trop. Med. Hyg. 37(3):624-628.

Cielsielski, C.A., L.E. Markowitz, R. Horsley, A.W. Hightower, H. Russell and **C.V. Broome.** 1988. The geographic distribution of Lyme disease in the United States. Ann. NY Acad. Sci. 539:283-288.

Feir, D. and **C. Reppell.** 1990. *Borrelia burgdorferi* in Missouri. In Missouri Academy of Science occasional paper #8: Lyme disease in the Southcentral United States (D. Feir, ed.).

Luckhart, S., G.R. Mullen and **J.C. Wright.** 1991. Etiologic agent of Lyme disease, *Borrelia burgdorferi,* detected in ticks (Acari: Ixodidae) collected at a focus in Alabama. J. Med. Entmol. 28:652-657.

Magnarelli, L.A. and **J.F. Anderson.** 1988. Ticks and biting insects infected with the etiologic agent of Lyme disease, *Borrelia burgdorferi*. J. Clin. Micro. 26(8):1482-1486.

Magnarelli, L.A., J.F. Anderson, C.S. Apperson, D. Fish, R.C. Johnson and **W.C. Chappel.** 1986. Spirochetes in ticks and antibodies to Borrelia burgdorferi in white-tailed deer from Connecticut, New York State, and North Carolina. J. Wildl. Dis. 22:178-188.

Magnarelli, L.A., J.H. Oliver, H.J. Hutcheson, J.L. Boone and **J.F. Anderson.** 1992. Antibodies to *Borrelia burgdorferi* in rodents in the eastern and southern United States. J. Clin. Micro. 30(6):1449-1452.

Masters, E. 1990. Case histories in Missouri. In Missouri Academy of Science occasional paper #8: Lyme disease in the Southcentral United States (D. Feir, ed.).

Miller, G.L., R.B. Craven, R.E. Bailey and **T.F. Tsai.** 1990. The epidemiology of Lyme disease in the United States 1987-1988. Lab. Med. 21(5):285-289.

Oliver, J.H., M.R. Owsley, H.J. Hutcheson, A.M. James, C. Chen, W.S. Irby, E.M. Dotson and **D.K. McLain.** 1993. Conspecificity of the ticks *Ixodes scapularis* and *I. dammini* (Acari:Ixodidae). J. Med. Entmol. 30(1):54-63.

Piesman, J. and **R.J. Sinsky.** 1988. Ability of *Ixodes scapularis, Dermacentor variabilis,* and *Amblyomma americanum* (Acari:Ixodidae) to acquire, maintain, and transmit Lyme disease spirochetes, (*Borrelia burgdorferi*). J. Med. Entmol. 25(5):336-339.

Schulze, T.L., G.S. Bowen, E.M. Bosler, M.F. Lakat, W.E. Parker, R. Altman, B.G. Ormiston and **J.K. Shisler.** 1984. *Amblyomma americanum*: a potential vector of Lyme disease in New Jersey. Science 224:601-603.

Schwann, T.G., W. Burgdorfer, M.E. Schrumpf and **R.H. Karstens.** 1988. The urinary bladder, a consistent source of *Borrelia burgdorferi* in experimentally infected white-footed mice (*Peromyscus leucopus*). J. Clin. Micro. 26(5):893-895.

Spielman, A., M.L. Wilson, J.F. Levine and **J. Piesman.** 1985. Ecology of *Ixodes dammini*-borne human babesiosis and Lyme disease. Ann. Rev. Entmol. 30:439-460.

Steer, A.C., S.E. Malawista, D.R. Snydman, R.E. Shope, W.A. Andiman, M.R. Ross and **F.M. Steele.**1977. Lyme arthritis: and epidemic of oligoarticular arthritis in children and adults in three Connecticut communities. Arthritis Rheum. 20:7-17.

Effect of Light, Nitrogen, and Water Management on Rice (*Oryza sativa*) Tolerance to Fenoxaprop

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Abstract

The effect of light intensity, nitrogen (N), and water management on rice (*Oryza sativa* cv. 'Newbonnet' and 'Lemont') tolerance to fenoxaprop {(±)-2-[4[(6-chloro-2-benzoxazolyl)oxy]phenoxy]propanoic acid} was determined in two field studies at the Rice Research and Extension Center, Stuttgart, AR, in 1988 and 1989. In one study, 'Newbonnet' rice was treated with 0.22 kg ai ha^{-1} fenoxaprop at 0, 1, 3, 5, 7, 10, 14, and 28 days after N application and flooding. Moderate to severe foliar chlorosis, stunting, and stand and yield reductions occurred when fenoxaprop was applied within 7 days after N application and flooding. None to slight injury or yield reduction occurred when fenoxaprop was treated later than 7 days after N application and flooding. In the second study, 'Lemont' rice grown in full or reduced (53%) sunlight and treated with preplant incorporated or preflood N was sprayed with 0.17 kg ai ha^{-1} fenoxaprop 1 week before or after flooding. Injury at early to midseason was greater in plants grown in reduced sunlight than in full sunlight. Also injury was greater when fenoxaprop was applied after flood than when applied before flood. Although rice generally recovered from injury, its tolerance to fenoxaprop was reduced by N application and flooding particularly in reduced sunlight.

Introduction

Barnyardgrass (*Echinochloa crusgalli* (L.) Beauv.] and bearded sprangletop [*Leptochloa fascicularis* (Lam.) Gray] are the most competitive of 70 weed species that infest drill-seeded rice in the U.S. and can reduce rice grain yields by 50 to 79% (Smith, 1968), (Smith, 1988a). Effective herbicides against these two grasses, including propanil [*N*-(3, 4-dichlorophenyl) propanamide], thiobencarb [*S*-[(4chlorophenyl) methyl] diethylcarbamothioate], pendimethalin [*N*-(1-ethylpropyl)-3, 4-dimethyl-2, 6-dinitrobenzenamine], or molinate [*S*-ethyl hexahydro-1*H*-azepine-1-carbothioate] (Smith and Khodayari, 1985; Smith, 1988b; Smith and Hill, 1990) usually require critical timing and appropriate water management for maximum efficacy (Richard and Street, 1984; Smith and Khodayari, 1985; Smith, 1988b; Smith and Hill, 1990). These herbicides usually do not adequately control weeds larger than the four-leaf stage and are not as effective against bearded sprangletop as they are against barnyardgrass (Richard and Street, 1984; Smith 1988b; Smith and Hill, 1990). Over the years their continued use coupled with the introduction of short-statured, short-season cultivars has increased bearded sprangletop infestations because of good barnyardgrass control (Khodayari et al., 1989).

Fenoxaprop is one of few rice herbicides that effectively controls bearded sprangletop and barnyardgrass (Khodayari et al., 1989). It belongs to a group of herbicides called polycyclic alkanoic acids (PCAs) which were introduced in the 1970s (Duke and Kenyon, 1988). Highly active against emerged annual and perennial grasses, PCAs are readily absorbed by roots and shoots and translocated into meristematic tissues where they inhibit fatty acid synthesis (Duke and Kenyon, 1988). At 0.10 to 0.20 kg ha^{-1}, fenoxaprop controls two- to six-leaf (pretillering) barnyardgrass and bearded sprangletop (Snipes and Street, 1987a; Khodayari et al., 1989). It offers more flexibility than other rice herbicides since it can be applied either preflood or postflood and also forms compatible combinations with propanil, thiobencarb or pendimethalin (Snipes and Street, 1987a; Khodayari et al., 1989).

Although highly selective to dicotyledonous crops, fenoxaprop usually causes no more than 30% injury to rice with the degree of tolerance varying with rate, cultivar, growth stage, or other conditions at the time of treatment (Snipes et al., 1987; Snipes and Street, 1987b; Khodayari et al., 1989; Griffin and Baker, 1990). The most common visible injury symptoms in the field are chlorosis, stunted growth, and stand reduction (Griffin and Baker, 1990), which are most apparent 5 to 10 days following application as a result of inhibited cell elongation or enlargement (Oosterhuis et al., 1990). Symptoms disappear within 1 to 2 weeks, and rice is usually fully recovered by 4 to 8 weeks after treatment. High rates (0.3 kg ha^{-1}) were observed to reduce grain yields (Snipes et al., 1987), but in most cases injury did not reduce yields at normal use rates (Snipes and Street, 1987b; Khodayari et al., 1989).

In dry-seeded rice, 50 to 65% of the total N is applied to rice 4 to 6 weeks after it has emerged and is at the four- or

five-leaf to tillering stages of plant development (Anonymous, 1990). Flooding usually follows within 0 to 5 days after N application to prevent N losses, enhance crop growth, suppress weeds, and enhance herbicide activity against weeds (Anonymous, 1990). Fenoxaprop injures very young rice seeedlings, thus it is applied to four- or five-leaf to tillering rice, which coincides with the time of N application and flooding. N application (Oosterhuis et al., 1990) and flooding (Snipes and Street, 1987b; Khodayari et al., 1989; Griffin and Baker, 1990) have been observed to decrease rice tolerance to fenoxaprop. Depending on herbicide rate, an interval of 1 - 10 days between fenoxaprop application and flooding is needed to minimize, if not avoid, rice injury with longer intervals needed at higher rates (Snipes et al., 1987). Decreased tolerance of rice to fenoxaprop following N application has been observed in the greenhouse (Oosterhuis et al., 1990). Sunlight intensity may also affect rice tolerance to fenoxaprop. While the effect of solar radiation on rice (Seshu and Cady, 1984) and the effect of sunlight on herbicide activity in various plants have been studied (Muzik and Mauldin, 1964; Hammerton, 1967; Muzik, 1976; Shaw et al., 1987; Dali-Armelina and Zimdahl, 1988; Regnier et al., 1988), the effect of light intensity on fenoxaprop activity is not fully understood.

This study was conducted to determine the effect of the following factors on rice tolerance to fenoxaprop: a) time of fenoxaprop application in relation to N application and flooding; and b) light intensity, time of N application, and time of fenoxaprop application.

Materials and Methods

General.--The studies were conducted in 1988 and 1989 at the Rice Research and Extension Center, Stuttgart, Arkansas. The soil was Crowley silt loam (Typic Albaqualfs, ph 6.5, 1% organic matter). Land was prepared by tilling the soil with a cultivator and cultipacked before and after seeding rice. Soil levees were constructed to separate replications.

Lemont or Newbonnet rice was drill-seeded at 135 kg ha^{-1} into 6 by 1 m plots consisting of seven rows spaced 18 cm apart at a depth of 2 cm. The plots were flush-irrigated one to two times before permanent flood to provide sufficient moisture for crop growth. Nitrogen as urea was broadcast by hand at rates and times of application required for each cultivar. To keep the plots weed-free, propanil applied sequentially or tank-mixed with either thiobencarb or bentazon [3- (1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide] was used. These treatments control weeds in rice with no adverse effects on rice growth and yield (Smith and Khodayari, 1985; Smith, 1988b; Smith and Hill, 1990).

Herbicide treatments were applied with a Co_2-pressurized backpack sprayer in 190 L ha^{-1}. Rice response to the fenoxaprop treatments was determined by visually rating crop injury on a scale of 0 (no injury) to 100 (plant killed) at various times after treatment (Frans et al., 1986). Morphological symptoms, plant height, and days to 50% heading were also recorded. Grain was harvested from 3 m^2 with a small plot combine, and yield was adjusted to 12% moisture.

Rice injury was analyzed as percentages and transformed percentages (arcsine or square root). Because the transformed analysis was not different from the nontransformed, the actual percentages are reported. A significant year by treatment interaction was obtained for both studies, thus data for both years were analyzed and presented separately.

Time of Fenoxaprop Treatment After N Application and Flooding.--Newbonnet rice was drilled on May 2, 1988, and April 17, 1989. Rice emerged 12 days after seeding (DAS) in 1988 and 21 DAS in 1989. Slow emergence in 1989 was due to low temperatures. Nitrogen (83 kg ha^{-1}) was applied 35 DAS (1988) and 49 DAS (1989) (23 and 26 days after emergence) immediately prior to applying permanent flood of 10 cm water to all plots. Fenoxaprop (0.22 kg ai ha^{-1}) was sprayed at 0, 1, 3, 5, 7, 10, and 14 days after flooding in 1988 and at 0, 1, 3, 5, 7, 10, 14, and 28 days after flooding in 1989. At the time of fenoxaprop application, rice was at the four-leaf to mid-tillering stages (20 - 48 cm tall) in 1988 and at early tillering to panicle initiation (25 - 66 cm tall) in 1989.

The first N at 84 kg ha^{-1} was applied before flooding when rice was in the early-tillering growth stage. Two more N applications of 34 kg ha^{-1} each were made; the first at panicle initiation when rice internodes were 1.3 cm and the second about 7 - 14 days after the first midseason application.

Rice injury ratings were taken weekly after each treatment until 31 days after the first fenoxaprop treatment in 1988 and 61 days after the first fenoxaprop treatment in 1989. Grain was harvested 130 DAS in 1988 and 139 DAS in 1989.

Treatments were arranged in a randomized complete block design and replicated three times. Data were subjected to analysis of variance and means separated by Least Significant Difference (LSD) at the 5% level.

Light Intensity, N Timing and Fenoxaprop Timing.--Lemont rice was drilled on April 25, 1988, and April 19, 1989. Rice emerged 18 DAS in 1988 and 22 DAS in 1989. At one week after rice emergence, the plots were subjected to full or reduced (53%) sunlight. Sunlight intensity was reduced to 53% by providing a black shade cloth canopy over and on the sides of plots that required shading. The

percent irradiance reduction in μE m^2 s^{-1} photosynthetic photon flux density (PPFD) under the canopy was measured compared to full sunlight (considered to be a maximum of 2000 μE m^2 s^{-1} PPFD at solar noon on a clear day) and was found to be in agreement with the manufacturer's specified shade level of 47% (Pallas et al., 1971). These plots were kept under the cnaopy for 4 - 5 weeks, and the canopy was removed one week after the last fenoxaprop application.

N was applied either preplant incorporated (PPI) or preflood (PF). PPI treatments were applied at 134 kg ha^{-1} before seeding then incorporated 1.5 cm into the soil with a tooth harrow. PF treatments were applied at 134 kg ha^{-1} 39 DAS (1988) and 51 DAS (1989) when rice was tillering and before the plots were flooded permanently. At midseason, two more N application of 34 kg ha^{-1} each were made; the first midseason N was applied when internodes were 1.3 cm (74 DAS in 1988 and 82 DAS in 1989) and the second midseason N was applied 7 - 14 days later (81 DAS in 1988 and 91 DAS in 1989).

Fenoxaprop (0.17 kg ai ha^{-1}) was applied either at 1 week before flooding to 15-cm rice at the four-leaf stage (32 DAS in 1988; 43 DAS in 1989) or at one week after flooding to tillering rice (30 - 50 cm tall) at 46 DAS in 1988 and 58 DAS in 1989.

Benomyl [methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate] at 1.1 kg ha^{-1} was applied 97 DAS to protect the crop from rice blast and sheath blight.

Crop injury ratings were made weekly from 7 - 47 days after the first fenoxaprop treatment. Grain was harvested 141 DAS in 1988 and 140 DAS in 1989.

Treatments were arranged in a split-plot design with light intensity as main plot and times of N and fenoxaprop application as subplots arranged as factorial within the split. In full-light and shaded treatments, fenoxaprop untreated rice that received N were included. Treatments were replicated three times, and means were separated by LSD at the 5% level.

Results and Discussion

Time of Fenoxaprop Treatment after N Application and Flooding.--In 1988, plants treated with fenoxaprop 0 to 7 days after N application and flooding had initial moderate injury of 40%, and those treated at 10 - 14 days after N application and flooding had initial slight injury of no more than 26% (Table 1). Although plants in all treatments eventually recovered, they yielded 5 - 16% less than untreated plants (Table 1). In 1989, there was a greater degree of injury of plants in all treatments (Table 2) than in 1988. Plants treated with fenoxaprop from 0 to 7 days after N application and flooding had initial moderate to severe injury of 40 - 90%, and those treated later than 7 days had initial slight to moderate injury of 33 - 40%. Recovery of plants treated later than 7 days was faster and more complete than those treated earlier than 7 days after N application and flooding. The 7-day treated plants never recovered from herbicide injury and yielded 83% less than untreated plants. The 0- to 5-day treated plants, which also had slow recovery, yielded 24 - 32% less than untreated plants. Those treated later than 7 days after N application and flooding yielded 1 - 19% lower, but these were not significantly different from untreated rice yields.

Table 1. Injury rating and yield of rice treated with 0.22 kg ha^{-1} fenoxaprop at various times after N application and flooding in 1988.

Time applied[a]	Injury rating at DAT[b] 14	31	Grain yield	Yield reduction
(DAF)	(——— % ———)		(kg ha^{-1})	(%)
0	40	2	6900	8
1	40	0	6530	13
3	40	0	6350	16
5	37	3	6570	13
7	43	3	7140	5
10	26	10	6320	16
14	0	22	6640	12
Untreated	0	0	7510	0
LSD (0.05)	12	7	NS	

[a]DAF = days after flooding

[b]DAT = days after first fenoxaprop treatment

Rice injury from fenoxaprop consisted of foliage desiccation, stunted growth, leaf chlorosis, and stand reduction, which was visible within 7 - 14 days after herbicide application. This agrees with observations in greenhouse studies (Oosterhuis et al., 1990) in which fenoxaprop-treated rice had inhibited leaf elongation within 4 days after treatment and growth and photosynthesis reduction of over 50% within 14 days after treatment. Growth inhibition was attributed to interference of the herbicide with cell division or elongation due to shortage of phospholipids necessary for cell membrane formation (Oosterhuis et al., 1990) as a result of fatty acid synthesis inhibition (Duke and Kenyon, 1988).

Greater plant injury in 1989 could have been caused by unusually high amounts of rain and associated cloudy conditions. During 1989 the total rainfall during the experimental period (April to September) was 73 cm, 38 cm of which occured in 27 days of June and July just before and at the time of fenoxaprop treatments. In 1988, the total

rainfall from April to September was 38 cm, 10 cm of which occured in 11 days of June and July just before and during fenoxaprop treatments. Greater activity of sethoxydim [2-[1-(ethoxyimino) butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one] when moisture was high or when there were above normal amounts of rainfall was observed in other studies (Retzinger et al., 1983; Chernicky et al., 1984).

Table 2. Injury rating and yield of rice treated with 0.22 kg ha^{-1} fenoxaprop at various times after N application and flooding in 1989.

Time applied	Injury rating at DAT[b] 10	43	71	Time to 50% heading	Grain yield	Yield reduction
(DAF)[a]	(——— % ———)			(days)	(kg ha^{-1})	(%)
0	60	27	33	87	6070	30
1	43	30	30	87	6660	24
3	50	40	43	89	5950	32
5	27	40	43	88	6200	29
7	10	90	87	91	1520	83
10	0	37	27	86	7060	19
14	0	33	20	86	8600	1
28	0	40	13	86	7030	19
Untreated	0	0	0	85	8700	0
LSD (0.05)	7	12	10	3	2190	

[a]DAF = days after flooding

[b]DAT = days after first fenosaprop treatment

Greatest injury in plants treated at 7 days after N application and flooding was apparently a result of optimum response of the plants to N. At this time, rice plants were about 30 to 40 cm tall and at the early tillering stage, which coincides with the rapid vegetative growth phase (Anonymous, 1990). As a rule, a young plant growing in good nutritional status is most susceptible to herbicides (Aberg, 1964; Hammerton, 1967; Muzik, 1974; Aberg and Stecko, 1976). Increased leaf mortality of greenhouse-grown rice plants treated with fenoxaprop and N fertilizer has been observed (Oosterhuis et al., 1990). Other studies also have reported a direct relationship between herbicide activity and N levels in the soil (Aberg, 1964; Hammerton, 1967; Aberg and Stecko, 1976). Oats (*Avena sativa* L.) treated with glyphosate [*N*-(phosphonomethyl) glycine] or fluazifop [(±)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid] and N showed greater injury of plants with high N treatments which was attributed to greater translocation of either herbicide to young shoots and meristems and to greater leaf area than plants with low N treatments (Dickson et al., 1990). High fertility and adequate water supply, in general, will increase plant susceptibility to herbicides because of increased leaf area, which results in greater herbicide interception or retention than in low fertility or low moisture conditions (Hammerton, 1967).

Fenoxaprop and other PCAs are usually applied as ester formulations. Once absorbed in the leaf, they are metabolized into the acid form, which is the active form and also the form in which they are translocated within the plant (Duke and Kenyon, 1988). Reduced metabolism of fluazifop-butyl ester to the acid form occurred when moisture was low resulting in low herbicide activity (Coupland and Bond, 1988). Thus it is possible that when moisture is high there is greater conversion of the ester to the acid form, which leads to greater herbicide activity than when moisture is low. In growth chamber, greenhouse, and field studies (Dortenzio and Norris, 1980; Grafstrom and Nalewaja, 1988; Kidder and Behrens, 1988; Dickson et al., 1990), decreased toxicity of PCAs, diclofop [(±)-2-[4-(2,4-dichlorophenoxy)phenoxy]propanoic acid], fluazifop, and haloxyfop[2-[4-[[3-chloro-5-(trifluoromenthyl)-2-2pyridinyl]oxy]phenoxy]propanoic acid] when moisture is low has been attributed to either reduced growth rate or to decreased herbicide retention, uptake, or translocation. When moisture is high, it is possible that these processes are enhanced leading to greater herbicide activity and hence greater plant injury than when moisture is low. Some studies (Snipes et al., 1987) observed the need for an interval of more than 1 – 5 days after flooding until applying fenoxaprop to minimize injury to rice. However, how flooding or excessive moisture increases rice susceptibility or fenoxaprop activity is not yet fully understood.

Light Intensity, N Timing, and Fenoxaprop Timing.--Significant interaction between light intensity and fenoxaprop treatments occurred in both years. In 1988, plants grown in reduced sunlight had greater initial injury than plants grown in full sunlight (Fig. 1). Within each light intensity, plants treated with fenoxaprop after flood had greater injury than those treated with fenoxaprop before flood. Thus, greatest injury was observed in plants grown in reduced sunlight and treated with fenoxaprop after flood. Although plants in all treatments eventually recovered within 47 days after treatment (DAT), those treated with fenoxaprop after flood and grown in reduced sunlight recovered slower than those grown in full sunlight or treated with fenoxaprop before flood (Fig. 2). By midseason, all plants had recovered fully so that yields were not different between treated and untreated rice (Table 3).

A similar trend, but with a higher degree of injury, occurred in 1989 (Fig. 3). Injury during this year was double and recovery was slower than in 1988, and plants with reduced sunlight in the after-flood treatments still had

slight injury of 30% by 54 DAT. Plants in full sunlight and before-flood treatments had fully recovered or had no more than 13% injury (Fig. 4). Eventually plants in all treatments fully recovered, and although those grown in full sunlight were shorter than those in reduced sunlight, treatments did not affect maturity dates or yields (Table 3). As in the flooding study, the high degree of injury observed in 1989 could have been due to the high amount of rain with associated cloudy conditions that occured this year particularly at the time of fenoxaprop treatments.

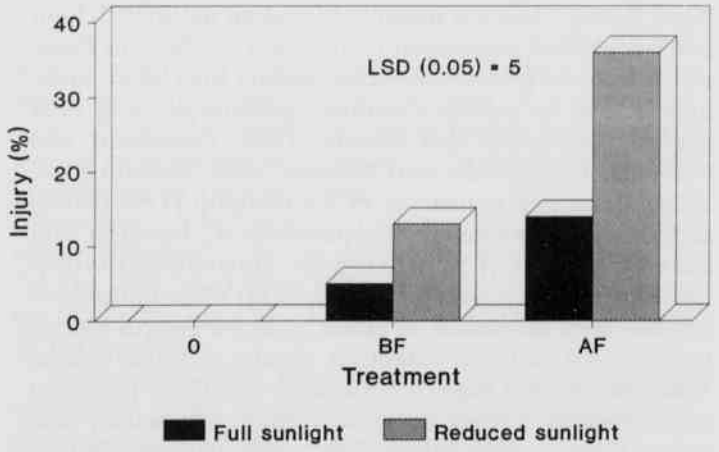

Fig. 1. Rice injury 28 days after treatment with before-flood (BF) or after-flood (AF) fenoxaprop at 0.17 kg ha^{-1} and grown in full or reduced sunlight in 1988.

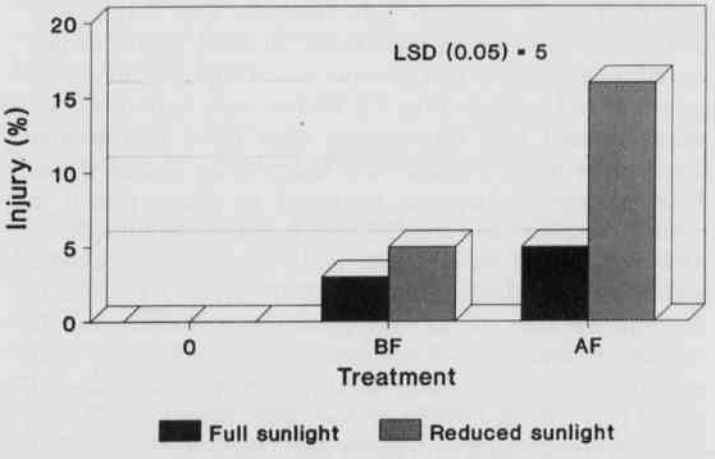

Fig. 2. Rice injury 47 days after treatment with before-flood (BF) or after-flood (AF) fenoxaprop at 0.17 kg ha^{-1} and grown in full or reduced sunlight in 1988.

Table 3. Height, days to heading and grain yield of rice treated with fenoxaprop at different light intensities and times of N application in 1988 and 1989.

Sunlight intensity, N timing, and herbicide[a]	Rate	Herbicide application Time[b]	Height[c]	Time to 50% heading[c]	Grain yield 1988	1989
	(kg ha^{-1})		(cm)	(days)	(kg ha^{-1})	
Reduced (53%)						
N PPI						
Fenoxaprop	0	--	79	84	6780	7950
Fenoxaprop	0.17	BF	85	84	8000	8230
Fenoxaprop	0.17	AF	76	84	7930	7770
N PF						
Fenoxaprop	0	--	79	85	8410	7510
Fenoxaprop	0.17	BF	78	87	8520	7590
Fenoxaprop	0.17	AF	72	86	7850	7590
Full (100%)						
Fenoxaprop	0	--	65	82	7420	8190
Fenoxaprop	0.17	BF	62	82	6830	8330
Fenoxaprop	0.17	AF	62	83	7400	8110
N PF						
Fenoxaprop	0	--	56	81	8230	6940
Fenoxaprop	0.17	BF	65	83	8410	7780
Fenoxaprop	0.17	AF	63	84	8420	8030
LSD (0.05)			11	NS[d]	NS	NS

[a]PPI = preplant incorporated; PF = preflood
[b]BF = before flood; AF = after flood
[c]Rice height and days to 50% heading were recorded only in 1989
[d]NS = not significant

Rice tolerance to fenoxaprop was decreased in reduced sunlight during the first 40 - 50 days after treatment. Increased toxicity of diphenamid (*N*, *N*-dimethyl-α-phenyl benzeneacetamide) and monuron [*N*'-(4-chlorophenyl)-*N*, *N*-dimethylurea] under reduced sunlight has been observed in other studies, apparently due to etiolated plant growth, which leads to plant susceptibility to herbicide injury (Minshall, 1957; Muzik and Mauldin, 1964; Minshall, 1969; Lynch and Sweet, 1971). Also, leaves grown in full sunlight are usually smaller with thicker cuticles and greater wax content than those grown in reduced sunlight, which would lead to reduced herbicide retention or uptake and less herbicide injury (Muzik and Mauldin, 1964). Other studies have observed fast herbicide degradation to non-toxic compounds in tomato (*Lycopersicon esculentum* Mill.) and red best (*Beta vulgaris* L.) grown under high light intensity (Lynch and Sweet, 1971; Stephenson et al., 1971). In our study, greatest injury in plants grown in reduced sunlight and treated with fenoxaprop after flood may have been due to cumulative

enhancing effects of increased uptake and reduced degradation on fenoxaprop activity, thus decreasing rice tolerance.

Our studies indicate that rice tolerance to fenoxaprop was reduced by N application, flooding, and reduced sunlight during the frist 50 days after herbicide treatment, but rice generally recovered from the injury. Fenoxaprop injury may thus be avoided or minimized by applying fenoxaprop before N application and flooding, or if it has to be applied after flooding, an interval of not less than 7 days between N application and flooding and fenoxaprop treatment should be allowed. This is much more critical during cloudy days or when there is an unusually high amount of rainfall.

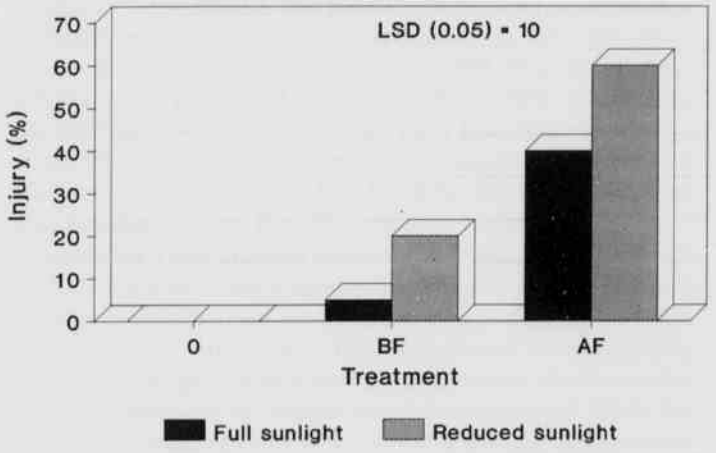

Fig. 3. Rice injury 27 days after treatment with before-flood (BF) or after-flood (AF) fenoxaprop at 0.17 kg ha^{-1} and grown in full or reduced sunlight in 1989.

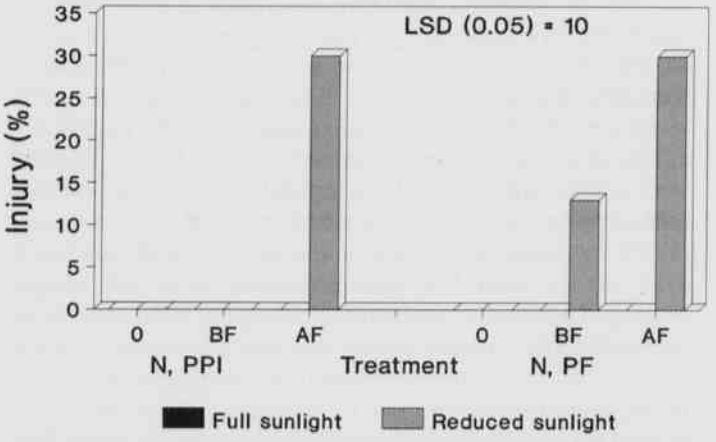

Fig. 4. Rice injury 54 days after treatment with before-flood (BF) or after-flood (AF) fenoxaprop at 0.17 kg ha^{-1} and grown at various light intensities with N applied preplant incorporated (PPI) or preflood (PF) in 1989.

Acknowledgements

We thank Howard L. Black and William T. Fox for technical assistance, Hoechst Roussel Agri-Vet for providing fenoxaprop samples and financial assistance, and the Rice Research and Promotion Board for partially funding this research.

Literature Cited

Aberg, E. 1964. Susceptibility: Factors in the plant modifying the response of a given species to treatment. Pp. 401-422, *In* The physiology and biochemistry of herbicides. L.J. Audus, ed Acad. Press, Inc., New York.

Aberg, E. and **V. Stecko.** 1976. Internal factors affecting toxicity. Pp. 175-201, *In* Audus, L.J., ed. Herbicides: Physiology, Biochemistry, Ecology, Vol. 2. Acad. Press, Inc., New York.

Anonymous. 1990. Rice Production Handbook, Misc. Pub. 192. Univ. Arkansas Coop. Ext. Serv., Little Rock, Arkansas. 59 pp.

Chernicky, J.P., B.J. Gorsett and **T.R. Murphy.** 1984. Factors influencing control of annual grasses with sethoxydim or RO-13-8895. Weed Sci. 32:174-177.

Coupland, D. and **C.M. Bond.** 1988. Enzymic de-esterification of fluazifop-butyl in leaf homogenates prepared from *Elymus repens* plants grown under contrasting environmental conditions. Pp. 93-98, *In* Proc. European Weed Res. Soc. Symp. Factors Affecting Herbicidal Activity and Selectivity.

Dali-Armelina, A.A. and **R.L. Zimdahl.** 1988. Effect of light on growth and development of field bindweed. (*Convulvulus arvensis*) and Russian knapweed (*Centaurea repens*). Weed Sci. 36:779-783.

Dickson, R.L., M. Andrews, R.J. Field and **E.L. Dickson.** 1990. Effect of water stress, N, and GA on fluazifop and glyphosate activity on oats (*Avena sativa*). Weed Sci. 38:54-61.

Dortenzio, W.A. and **R.F. Norris.** 1980. The influence of soil moisture on the foliar activity of diclofop. Weed Sci. 28:534-539.

Duke, S.O. and **W.H. Kenyon.** 1988. Polycyclic alkanoic acids. Pp. 71-116, *In* Herbicides: chemistry, degradation, and mode of action, (P.C. Kearney, and D.D. Kaufman, eds).Vol. 3. Marcel Dekker, Inc. New York, NY.

Frans, R., R. Talbert, D. Marx and **H. Crowley.** 1986. Experimental design and techniques for measuring and analyzing plant responses to weed control practices. Pp. 29-46, *In* Research methods in weed science, 3rd ed. (N.D. Camper, ed) South. Weed Sci. Soc., Champaign, IL.

Grafstrom, L.O. and **J. D. Nalewaja.** 1988. Uptake and translocation of fluazifop in green foxtail (*Setaria*

viridis). Weed Sci. 36: 153-158.

Griffin, J.L. and **J.B. Baker.** 1990. Tolerance of rice (*Oryza sativa*) cultivars to fenoxaprop, sethoxydim, and haloxyfop. Weed Sci. 38:528-531.

Hammerton, J.L. 1967. Environmental factors and susceptibility to herbicides. Weeds 15:330-336.

Khodayari, K., P. Nastasi and **R.J. Smith, Jr.** 1989. Fenoxaprop for grass control in dry-seeded rice (*Oryza sativa*). Weed Technol. 3:131-135.

Kidder, D.W. and **R. Behrens.** 1988. Plant response to haloxyfop as influenced by water stress. Weed Sci. 36:305-311.

Lynch, M.R. and **R.D. Sweet.** 1971. Effect of environment on the activity of diphenamid. Weed Sci. 19:332-337.

Minshall, W.H. 1957. Influence of light on the effect of 3-(p-chlorophenyl)-1, 1-dimethylurea on plants. Weeds 5:29-33.

Minshall, W.H. 1969. Effect of nitrogenous materials on the uptake of triazine herbicides. Weed Sci. 17:197-201.

Muzik, T.J. 1976. Influence of environmental factors on toxicity to plants; Pp. 203-247, *In* Herbicides: physiology, biochemistry, ecology, Vol. 2. (L.J. Audus, ed.), Acad. Press, New York.

Muzik, T.J. and **W.G. Mauldin.** 1964. Influence of enviroment in the response of plants to herbicides. Weeds 12:142-145.

Oosterhuis, D.M., S.D. Wullschleger, R.E. Hampton and **R.A. Ball.** 1990. Physiological responses of rice (*Oryza sativa*) to fenoxaprop. Weed Sci. 38:459-462.

Pallas, J.E. Jr., J.D. Neves and **E.R. Beaty.** 1971. Light quality under Saran shade cloth. Agron. J. 63:657-658.

Regnier, E.E., M.E. Salvucci and **E.W. Stoller,** 1988. Photosynthesis and growth response to irradiance in soybean (*Glycine max*) and three broadleaf weeds. Weed Sci. 36:487-496.

Retzinger, E.J. Jr., R.L. Rogers and **R.P. Mowers.** 1983. Performance of BAS-9052 applied to johnsongrass (*Sorghum halepense*) and soybean (*Glycine max*). Weed Sci. 31:796-800.

Richard, E.P. and **J.E. Street.** 1984. Herbicide performance in rice (*Oryza sativa*) under three flooding conditions. Weed Sci. 32:157-162.

Seshu, D.V. and **F.B. Cady.** 1984. Response of rice to solar radiation and temperature estimated from international yield trails. Crop Sci. 24:649654.

Shaw, D.R., H.R. Smith, A.W. Cole and **C.E. Snipes.** 1987. Influence of environmental factors on smallflower morning glory (*Jacquemontia tamnifolia*) germination and growth. Weed Sci. 35:519-523.

Smith, R.J. Jr. 1968. Weed competition in rice. Weed Sci. 16:252-255.

Smith, R.J. Jr. 1988a. Weed thresholds in southern U.S. rice, *Oryza sativa*. Weed Technol. 2:232-241.

Smith, R.J. Jr. 1988b. Weed control in water- and dry-seeded rice. Weed Technol. 2:242-250.

Smith, R.J. Jr. and **J.E. Hill.** 1990. Weed control technology in U.S. rice. Pp. 314-327, *In* Pest management in rice. (B.T. Grayson, M.B. Green, and L.G. Copping, eds.), Elsevier Sci. Publishers Ltd., England.

Smith, R.J. Jr. and **K. Khodayari.** 1985. Herbicide treatments for control of weeds in dry-seeded rice (*Oryza sativa*). Weed Sci. 33:686-692.

Snipes, C .E. and **J.E. Street.** 1987a. Fenoxaprop for postemergence barnyardgrass (*Echinochloa crusgalli*) control in rice (*Oryza sativa*). Weed Sci. 35:224-227.

Snipes, C.E. and **J.E. Street.** 1987b. Rice (*Oryza sativa*) tolerance to fenoxaprop. Weed Sci. 35:401-406.

Snipes, C.E., J.E. Street and **D.L. Boykin.** 1987. Influence of flood interval and cultivar on rice (*Oryza sativa*) tolerance to fenoxaprop. Weed Sci. 35:842-845.

Stephenson, G.R., D.R. Dilley and **S.K. Ries.** 1971. Influence of light and sucrose on N-glucosyl pyrazon formation in red beet. Weed Sci. 19:406-409.

GENERAL NOTES

Sinkhole Excavations in Peccary Cave, Newton County, Arkansas

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Peccary Cave in eastern Newton County, Arkansas, is the most intensely analyzed Pleistocene vertebrate site in Arkansas. Dr. James H. Quinn, Geology Department, University of Arkansas at Fayetteville, secured a National Science Foundation grant that funded nearly continuous excavations of more than 20 areas within the cave from September, 1967, through August, 1969. Results of these efforts were published by Davis (Proc. Ark. Acad. Sci., 23:192-196, 1969), Quinn (Proc. 24th Intern. Geol. Cong., 12:89-96, 1972), Semken (*In* Contributions in Quaternary Vertebrate Paleontology, Pp. 405-432, 1984) and Stafford and Semken, (Curr. Res. Pleistocene, 7:129-132, 1990).

Semken's 1984 analysis of remains from Trenches 8, 13, and 15 allowed a six-stage reconstruction of the Newton County biota for the Late Pleistocene continuing through much of the Holocene. He envisioned a community 16,700 years ago "dominated by individuals characteristic of a cool steppe with coniferous forest patches." With the passage of time, species with boreal affinities disappeared from the cave environs and the modern closed deciduous forest biome developed some time after 2290 yrs. B.P. The stratigraphic sequence to support Semken's conclusions was based on correlating three trenches from two areas of the cave. In 1969 it was established that there were 4.26 m of sediments beneath the sinkhole entrance to Peccary Cave, but the time span they represented was not determined. When excavations were resumed in the cave in 1992, the thick, presumably unbroken, sinkhole sequence seemed to offer the opportunity to verify Semken's work. Squares 1 and 2 were excavated on the east side of the sinkhole with the additional goal of opening up any continuation of a series of dome-pit features trending in that direction. Before these squares were excavated to 20 cm depth, the solid limestone wall and floor of the cave blocked further progress. Excavations were then begun on the west side of the sinkhole debris cone to take advantage of 2.13 vertical m of exposed sediment.

The face of the sinkhole fill was excavated to a depth of 2.28 m in 15 cm levels. Sediments were spread on 0.91 x 2.44 m screen-wire covered frames to dry the clays in the matrix as thoroughly as possible. Any visible bone and charcoal was collected while the sediments were still on the frames. Dry sediments were then washed through a stack of 2.2 cm, 1.1 cm, 0.5 cm and 0.2 cm screens to separate the sediments into uniform size fractions so that large rocks would not break small bones. Teeth, bone, and charcoal were collected furing the washing process. Residue that passed through the 0.2 cm mesh was rewashed through window screen baskets to separate the remaining clay from minute specimens. When dry, the different sized sediments were again examined for specimens.

The use of the different sized screens for washing the sediments is a modification of the technique pioneered by C. W. Hibbard (Michigan Univ. Mus. Paleontology Contr. 8(2) :7-19, 1949) in southwestern Kansas. Screen-bottomed boxes patterned after his model were used in the 1967-69 excavations. Our procedure seemed to produce less breakage of specimens and took approximately one 10-h day to process each 15 cm level of sediments.

The taxa of mammals recovered in the present study and their abundance in the various levels are recorded in Table 1. Many of the categories include more than one species, and more detailed study is expected to add several more. Excluding carnivores, the total Minimum Number of Individuals (MNI) from the 14 levels is 203. This number is only 17% of the size of the sample available for Semken's 1984 study. It will be desirable to increase our sample size by sampling additional squares as our study proceeds.

Deer mice, wood rats, and shrews are the most abundant taxa (comprising 71.7%) of Semken's study. They represent 68% of the MNI in the present study, but ground squirrels are more abundant (24) than shrews (16). Semken reports the pine vole throughout his sample, but it is concentrated in the top five levels under the sinkhole. The gopher (*Geomys* sp.) was represented by 120 individuals throughout Semken's sample. We have recovered but one and that in the deepest level processed to date. The largest animal recovered under the sinkhole (an unidentified juvenile carnivore) is much smaller than the peccaries, dire wolves, and even musk oxen recovered in the 1967-1969 excavations. These differences may be due to our smaller sample size or may be caused by the different areas of the cave having acquired their specimens by different mechanisms. The larger numbers of micromammals in Semken's 1984 study probably represent some sort

Journal of the Arkansas Academy of Science, Vol. 47 [1993], Art. 1

of raptorial bird pellet accumulation. Some of the large mammals Quinn studied clearly inhabited the cave as evidenced by neonatal specimens of *Platygonas compressus*. The sinkhole specimens may be mainly accidental victims of this natural trap, although they may not have been immediately killed by falling. Many of the post-cranial bones recovered show extensive evidence of gnawing. Countless other specimens may have been completely consumed by rodents.

Table 1. Minimum Numbers of Individuals of Mammal Species Collected By Level From Sinkhole Square Four, Peccary Cave.

Lev.	Deer Mouse	Wood Rat	Shrew	Vole	Ground Squirrel	Bat	Tree Squirrel	Ground Hog	Rabbit	Gopher
1	4		2	3						
2	6	4		2	3					
3	6	1		1	1	1				
4	6	2		2		1				
5	13	2	2	2	2	2				
6	10	5	1		6	2	2	1		
7	14	5	1		2	4	1		1	
8	4	3			2	1			1	
9			1			3				
10	6	3	3	1	2	1				
11	2	3	1		3	1				
12	4	3	1	2	2	1				
13	8	2	1		1			1	1	
14	5	2	3			1		1		1
Total	88	34	16	13	24	18	3	3	3	1

Table 2. Minimum Numbers of Individuals of Amphibian and Reptile Species Collected From Sinkhole Square Four, Peccary Cave.

Level	Salamanders*	Anurans	Snakes**	Lizards
1		2	1	
2		9	3	2
3		1	1	5
4		1	1	4
5	1	3	2	5
6	1	4	3	1
7	1	2	2	2
8		2	1	1
9	1	1		1
10	1	2	1	2
11	1	2	1	2
12	1	1	1	1
13		1	1	1
14		1		
Total	7	32	18	27

* All are *Ambystoma*.
** All are cranial elements.

The amphibian and reptile specimens recovered in the present study are presented in Table 2. The two clusters of *Ambystoma* may represent only two individuals. Anurans dominate the herptile collection at the present level of identification. The pattern noticed by Davis (Unpublished Master's thesis, Univ. Arkansas Fayetteville, 1973) that there are more toads (*Bufo*) in the cave rather than true frogs, *Rana*, or smaller forms such as *Hyla*, or *Pseudacris* still seems to hold true. The toad's more terrestrial existence and willingness to wander farther from standing bodies of water may explain this distribution.

Thousands of snake vertebrae have been collected but not studied. Minimum number of individuals have been calculated from cranial elements. One poison fang is clear evidence of pit vipers being in the fauna.

Lizards are more abundant than snakes in terms of MNI counts, which are usually based on numbers of dentaries or parietals. *Crotaphytus, Sceloporus, Ophisaurus, Cnemidophorus,* and *Eumeces* were identified from Peccary Cave by Davis (1973), and all of the present specimens can probably be assigned to those same taxa.

To date, 31,256 pebbles that fell through one inch square mesh hardware cloth but were caught on half inch square mesh hardware cloth have been collected, referred to a stratigraphic formation, counted, and weighed in lots of 50 or fractions thereof. While most of the cave is within Ordovician limestone, such as Plattin, the top of the sinkhole is within the hematite-stained St. Joe limestone member of the Boone Formation. Chert has been washed into the cave since the sinkhole broke through the hillside. Only 6.8% of the pebbles are assigned to the St. Joe, 0.6% to the Plattin limestone, and the remaining 92.6% seem to be insoluble chert derived from the Boone formation. It is anticipated that with increasing depth, indicating even longer times exposed to the dissolving power of water entering the sinkhole, the relative abundance of limestone will decrease even more. At some depth, before the opening of the sinkhole, the fill material is expected to be Ordovician limestone clasts in insoluble clay.

To the present, 2666 St. Joe specimens and 8210 chert fragments which were too large to fall through 2.5 cm square hardware cloth have been analyzed. Table 3 demonstrates that the ratio between these lithologies is not constant, and we believe it is varying in a non-random fashion. There seems to be an overall trend toward diminishing amounts of the St. Joe limestone with two centering on Level 4 (45 – 60 cm) and Level 10 (1.37 – 1.52 m). We await radiocarbon dates from the abundant charcoal samples which have been collected to determine if this pattern represents non-uniform rates of deposition. It is possible that periodic forest fires produce the charcoal, strip major portions of the vegetation from the hillside above the sinkhole, and allow accelerated erosion and transport to the cave of the Boone chert regolith (centering on Levels 3, 8,

and 13).

Table 3. Pebble Types Collected From Sinkhole Square Four, Peccary Cave.

Level	Boone	Plattin	St. Joe	Dripstone
1	252	1	152	4
2	663	7	394	14
3	321		102	1
4	238	8	170	23
5	198	7	131	7
6	682	39	361	
7	740	24	184	
8	623	9	117	2
9	427	2	140	
10	502	7	282	1
11	1055	10	208	4
12	959	7	118	3
13	935	5	90	3
14	615	3	88	
Total	8210	129	2666	62

We wish to acknowledge the continuing friendship and assistance of Jack and Lois McCutcheon throughout this project. Carl and Jerome McCutcheon rendered vital assistance in reopening the cave and restoring the electrical system after a lapse of 20 years. Felisha McCutcheon, Carla McCutcheon, and Kim Bruce were reliable assistants in sorting specimens from concentrate. Elizabeth Hawk Davis provided editorial assistance.

A Three Year Study on a Cypress-Tupelo Swamp in Independence County, Arkansas

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According to Section 404 of the Clean Water Act in the Federal Manual for Identifying and Delineating Jurisdictional Wetlands (1989), a wetland is defined as an area that is inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions. The cypress-tupelo swamp in this three year study clearly fits this definition.

The study area is located in Township 12N, Range 3W, Section 25 northeast of Cord, Arkansas in Independence County. Rouse (1991) describes Section 25 as typical bottomland hardwood forest. Only a remnant of the swamp called Hattie's Brake remains due to heavy clearing for agricultural purposes. Hattie's Brake boarders area farmlands on three sides and is adjacent to the Black River on the other side. Rouse (1991) describes the remnant as having taken on a horseshoe or C-shape that covers 8.1 hectares whose ends are maintained by beaver dams at both extremes. Surface run off from the surrounding farmlands freely enters Hattie's Brake as do several small creeks and a slough that help to maintain the water level of the swamp. Periodically the swamp is flooded from the Black River. All of these inputs bring in nutrients from the outside to support the fauna and plant populaton of the swamp.

The data for six parameters were collected over a three year period from Hattie's Brake and then compared to data from a southern Illinois cypress-tupelo swamp as reported by Mitsch and Gosselink (1986) from studies done by Dorge, Mitsch and Weimhoff in 1984. The data presented in Table 1 from the swamp is very similar to that previously reported from the Black River at Jacksonport (Petersen 1988). The six parameters studied were conductivity (CND), pH, turbidity, dissolved oxygen (D.O.), nitrate and phosphate concentrations.

Hattie's Brake seems to consist primarily of the soil type labeled Amagon-Askew-Forestdale which is defined as deep, level to gently undulating, poorly to moderately well drained, loamy soil (Ferguson et al., 1982). These soils are found on bottomlands along the White and Black Rivers and are moderately suited to cultivated crops that have a short growing season (Ferguson et al., 1982).

Collection trips were made mostly on a weekly basis from May to September over the three year study except when flooding from the Black River occurred. All physical and chemical parameters were measured from the water samples collected in 1000 mL Wheaton collection bottles. The physical tests were performed in the field, and the chemical tests were done both in the field and in the Arkansas College water analysis lab. Franson (1985) provided the procedures used. Specific instruments/methods for these parameters are discussed as follows: pH–Hach One pH meter; Dissolved Oxygen–Hach Portable Dissolved Oxygen meter, membrane electrode method; Conductivity–Hach Conductivity/TDS meter; Turbidity–Hach Portable Turbidimeter; Nitrate concentration–cadmium reduction method using NitraVer6 and NitraVer3 nitrate reagent powder pillows; Phosphate concentration–ascorbic acid method using PhosVer3 phosphate reagent powder pillows. The Turner spectrophotometer Model 330 was used in the determination of the concentrations of the nitrates and phosphates present. Individual results for the physiochemical tests are given in Table 1. Table 2 includes a comparison of data that was collected from a southern Illinois cypress-tupelo swamp and the Independence County Arkansas cypress-tupelo swamp. All of the parameters except for turbidity and nitrate concentration from the Arkansas cypress-tupelo swamp are above those values for the southern Illinois cypress-tupelo swamp. However, more samples were taken for the Independence County Arkansas cypress-tupelo swamp than for the southern Illinois cypress-tupelo swamp.

The conductivity is consistently higher in the Arkansas cypress-tupelo swamp than for the southern Illinois cypress-tupelo swamp. Although there was no data taken for ion concentration over the entire three years, the Arkansas cypress-tupelo swamp would tend toward greater presence of conducting ions or electrolytes. This higher conductivity is also consistent with the data from the Black River because the conductivity for the Black River is lower than that for the Arkansas cypress-tupelo swamp. Welch (1952) has related this higher conductivity with greater biological productivity.

The dissolved oxygen averaged 3-4 mg/l. The data between May 29, 1991 to July 2, 1991 are probably skewed because of instrument malfunction. Therefore, the dissolved oxygen data of the Arkansas cypress-tupelo swamp during that year is not comparable to other studies. The data for 1990 and 1992 are comparable to the Illinois data (Table 2).

The pH of the Arkansas cypress-tupelo swamp was more

basic than the southern Illinois cypress-tupelo swamp. This implies that fewer hydrogen ions are present in the Arkansas cypress-tupelo swamp. This could also imply that the higher conductivity may be due mostly to salts rather than to inorganic acids and bases. The swamp was probably very high in calcium ions due to the presence of limestone ($CaCO_3$) in surrounding lands. This abundance of calcium mostly comes from the Black River.

The nitrogen concentration was lower in the Arkansas cypress-tupelo swamp than the southern Illinois cypress-tupelo swamp. Nitrate concentrations averaged 0.22 during the three years that data was collected. This value of 0.22 is reasonable because the nitrate concentration from the Black River in Table 2 has a mean value of 0.22. Nitrate generally occurs in trace quantities in surface water but may attain high levels in some groundwater (Franson 1985). Nitrate is also an essential nutrient for many photosynthetic autotrophs and in some cases has been identified as the growth-limiting nutrient. It is evident that the Arkansas cypress-tupelo swamp supports a large population of plants both along its banks and on it surface.

The phosphate concentration for the Arkansas cypress-tupelo swamp is higher than that for the southern Illinois cypress-tupelo swamp. This increase may be due to the ascorbic acid method used to test for the phosphate. Large amounts of turbidity could cause higher phosphate readings because the acid present in the powder pillow could dissolve some of the suspended particles and yield a higher reading. This seems unlikely because the turbidity recorded for the Arkansas cypress-tupelo swamp. The increase in the phosphate concentration is almost assuredly due to the run-off from the agricultural land that surrounds the swamp. The fertilizers used on the crops are carried with surface water with storm run-off and to a lesser extent with melting snow (Franson 1985). Phosphate is essential to the growth of organisms and can be the nutrient that limits the primary productivity of a body of water. The Arkansas cypress-tupelo swamp has been found to support a large fauna of aquatic invertebrates and other micro-and macroorganisms (Rouse et al., 1991).

Turbidity was one of the parameters that was measured to be lower in the Arkansas cypress-tupelo swamp than in the southern Illinois cypress-tupelo swamp. The fluctuation of the turbidity was attributed to changes in rainfall since murkiness increased after heavy rains. It can be concluded from the Arkansas cypress-tupelo swamp data that the Arkansas cypress-tupelo swamp has a fairly high sedimentation rate, yielding fairly clear water. The high tubidity can be used to explain the high phosphate concentration that was recorded.

The results obtained during the study were comparable with those obtained in Illinois, except for conductivity, turbidity, and pH (Table 2). Conductivity in the study area compared to that of the Cache River in Illinois, but was much higher than that reported for the Black River. Decomposing organic material in the swamp would account for the lower dissolved oxygen reading, while the stream load of the Black River would increase its turbidity.

Table 1. Ecological Data for Hattie's Brake.

Date 1990	CND (mS/m)	pH	Turbidity (NTU)	D.O. (Mg/L)	(NO_3)	(PO_4)
June 26	21	7.43	2.4	----	22	.64
July 3	23	7.20	14.0	4.2	.29	.12
July 10	27	7.27	15.0	2.8	.22	.10
July 16	24	7.04	4.1	2.3	.22	.31
July 24	22	7.77	6.0	4.4	.25	.24
Aug. 1	24	7.30	.39	3.2	.22	.20
Aug. 7	24	7.27	.75	2.4	.26	.19
Aug. 15	23	7.45	.30	2.5	.19	.05
Sept. 25	30.5	7.02	.53	2.45	.22	.40
Oct. 30	33	----	2.8	----	.27	.332
Nov. 16	27	7.65	6.6	2.7	.222	.60
Dec. 7	30	6.57	.67	3.4	.22	.10
Average	26	7.27	4.46	3.04	.234	.274

Date 1991	CND (mS/m)	pH	Turbidity (NTU)	D.O. (Mg/L)	(NO_3)	(PO_4)
May 29	31	7.45	.40	8.1	.30	.64
June 6	25	7.00	6.6	10	.37	.24
June 11	25	7.76	.38	11.5	.30	1.12
June 18	25	7.38	.37	8.8	.30	.38
June 27	31	7.38	4.7	8.4	.15	.44
July 2	28	7.30	8.2	6.8	.07	.84
July 11	30	7.35	4.1	----	.15	.04
July 17	26	6.97	29	----	.30	.14
July 22	26	7.19	.63	----	.22	.14
July 29	28	7.49	74	4.3	.52	.54
Aug. 5	25	6.92	7.9	----	.15	.14
Aug. 12	26	6.81	33.5	----	.34	.19
Aug. 19	31	7.51	62	----	.37	.34
Sept. 2	32	6.64	29	----	.30	.19
Sept. 16	25	6.52	.64	----	.15	.14
Oct. 4	27	7.35	.55	2.5	.74	.13
Oct. 18	38	7.67	.79	2.6	.18	.20
Average	28	7.22	15.46	7.0	.29	.34

Date 1991	CND (mS/m)	pH	Turbidity (NTU)	D.O. (Mg/L)	(NO_3)	(PO_4)
Jan. 21	44	8.25	6.3	4.2	.37	.28
April 10	34	6.63	53	6.3	.28	.10
May 14	33	7.60	7.5	4.6	.19	.48
May 20	24	7.78	.57	3.6	.15	.18
May 27	24	7.91	.27	4.8	.07	.22
June 10	22	7.19	.36	5.2	.07	.12
June 24	24	7.51	.67	2.1	0.0	.22
July 7	39	7.41	48	----	0.0	3.16
July 28	48	7.65	27	----	.07	.12
Aug. 4	51	7.50	1.7	----	.07	3.12
Aug.10	47	7.44	2.0	----	.12	.52
Aug. 13	62	-7	2.8	3.8	.15	.30
Aug. 17	58	----	.61	----	.37	.05
Sept. 11	62	-7	26	2.2	.04	.07
Sept. 30	76	-7	.34	2.2	.12	.04
Average	43	7.42	11.81	3.9	.14	.60

Table 2. Comparison of Selected Data from a southern Illinois cypress-tupelo swamp and its Cache River and an Arkansas cypress-tupelo swamp and its Black River.

	CND (mS/M)	pH	Turbidity (NTU)	D.O. (Mg/L)	(NO_3)	(PO_4)
Southern Illinois cypress-tupelo swamp	5.1-24 (9)*	5.8-6.5 (4)	23-690 (8)	0.9-4.0 (5)	0.6-4.7 (6)	0.06-0.28 (9)
Cache River in southern Illinois	35.2 (9)	7.3 (4)				
Independence County Arkansas cypress-tupelo swamp	33.33 21-76 (44)	7.3 6.52-8.25 (42)	10.58 0.27-74 (44)	4.65 2.1 (20)	0.22 0.0-.74 (44)	0.41 0.04-3.16 (44)
Black River in Arkansas	2.93 (56)	8.1 (93)	31 (30)	9.5 (92)	0.22 (39)	

*numbers in parenthesis indicate number of samples

Acknowledgements

Permission for the study was given by Jim Barnett, who was representative of the owners, and Don Coleman, who was representative of the leasors. A faculty research grant from Arkansas College provided support for the three year study.

Literature Cited

Dorge, Carol L., William J. Mitsch and **John R. Weimhoff.** 1984. Cypress Wetlands in Southern Illinois. Pp. 393-404, *In* Cypress Swamps (Ewel, Katherine Carter and Howard T. Odum eds.) University of Florida Press, Gainesville, Florida, xi + 472 pp.

Ferguson, Dick V., J. Sidney Lowerence and **Clarence E. McFadden.** 1982. Soil Survey of Independence County Arkansas. U.S.D.A. Soil Conservation Service. Washington, D.C. 148 pp.

Field Interagency Committee for Wetland Delineation. 1989. Federal Manual for Identifying and Delineating Jurisdictional Wetlands. U.S. Corps of Engineers, USEPA; U.S.F.&W.S. and USDA Soil Conservation Service, Washington, D.C. Cooperative technical publication. 76 pp.

Franson, Mary Ann. Managing Editor. 1985. Standard Methods for the Examination of Water and Waste Water. Amer. Pub. Health Association. Washington, D.C. 1268 pp.

Mitsch, William J. and **James G. Gosselink.** 1986. Wetlands. Van Nostrand Reinhold. New York, N.Y. 539 pp.

Petersen, James C. 1988. Statistical Summary of Selected Water-Quality Data (Water Years 1975 Through 1985) For Arkansas Rivers and Streams. Arkansas Geological Commission. Little Rock, Arkansas. 189 pp.

Ichthyofauna of a Cypress-Tupelo Swamp

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The objectives of this paper are to list the families and species of ichthyofauna collected in Hattie's Brake and the immediate surrounding area, and to note the presence of icthyofauna not commonly found in the Black River drainage. Hattie's Brake, which can be classified as an alluvial river swamp, is a small cypress-tupelo swamp surrounded by cultivated fields and located in the Black River bottoms in Independence County, 6.4 km east of Cord, Arkansas (Mitsch and Gosselink, Wetlands, 1986). The exact area of study was concentrated in 12N; 3W; 25. Those sections immediately surrounding the study area (e.g., Sections 23, 24 and 26) are currently used for agricultural purposes, such as growing rice, soybeans, and sorghum.

Hattie's Brake takes the form of an oxbow lake, which may have resulted when meanders from the nearby Black River were cut off by sedimentary deposits. The swamp itself covers approximately 8.1 ha in permanently standing water on a 67 m contour. Its depth ranges from 91 cm to 183 cm, with 91 cm to 122 cm being the average depth. It has a soft mud bottom which is laden with debris.

Both Saltwork and Milligan Sloughs drain into the swamp, but only Milligan Slough feeds directly into the swamp year around. During flood season the Black River, which lies less then 1.6 km to the south of Hattie's Brake, rises from its normal 64 m above sea level to 67 m or above, thus backing up water into tributaries which overflow into the swamp.

Hattie's Brake has remained permanently flooded throughout the year, with only seasonal fluctuations in water level, for between 10 and 15 yrs. Extremely low water levels occurred during the summer and early fall of 1991, when the water level of the swamp fell to such a point that the arm of Milligan Slough which feeds into the brake was reduced to small isolated pools of standing water.

An increase in the concentration of dissolved nutrients can be seen after seasonal flooding of the Black River and other tributaries occurs and the water levels return to normal. This nutrient increase along with slowly flowing waters and low turbidity, not only encourages the growth of bald cypress and water tupelo, but also leads to the development of healthy growths of duckweed mats (e.g., *Lemna* spp. and *Spirodela* spp.) and to a large and diverse population of invertebrates including crayfish, snails, freshwater shrimp, clams, amphipods, and insects. The presence of bald cypress and water tupelo in combination with the growth of duckweed mats and invertebrates play an important role in both the spawning and breeding habits of the many fish species that premanently inhabit similar swamps (Mitsch and Gosselink, Wetlands, 1986).

During a three year study of Hattie's Brake and the immediate surrounding area, excluding the Black River, fish were collected from various sites in and around the swamp. The sites ranged from isolated pools to sloughs that flowed directly into the swamp to backwaters created by beaver dams to the main body of the swamp. A majority of the specimens collected came from the main body of the swamp, with the second largest sampling coming from backwaters and sloughs, isolated pools were the least sampled because of the great fluctuation in water level. Most of the specimens were collected during the spring, summer, and early fall, with only a few specimens collected in late fall and winter.

Three seines, sizes 1.2 m x 3.1 m, 1.2 m x 6.1 m, and 1.8 m x 9.1 m, in addition to several kick nets were used to capture the fish from these areas. The fish were temporarily stored in 10% formalin once they were collected and then preserved permanently in 70% isopropanol. Keys from H.W. Robison's and T.M. Buchanan's (1988) book *Fishes of Arkansas* and W.L. Pflieger's, (1978) book *The Fishes of Missouri* were used to confirm the identification of fish species.

Thirty-one species of fish representing fourteen families have been identified as permanent inhabitants of Hattie's Brake and the immediate surrounding area as listed in Table 1, the list compiled probably represents the majority of the ichthyofauna of the swamp. It is interesting to note that four species of fish, not commonly found within the Black River or the area surrounding it, were collected at Hattie's Brake. The flier (*Centrarchus macropterus*), which was collected from several different sites in the swamp, has an erratic distribution within the state and is not commonly found in the northeastern region of Arkansas. The orangespotted sunfish (*Lepomis humilis*), which has a widespread distribution over the state but isn't commonly found in the Black River, was also found at the swamp. The other two species collected, the swamp darter (*Etheostoma fusiforme*) and the slough darter (*Etheostoma gracile*), also have a limited distribution within the Black River system. The swamp darter, which was collected from two different areas at Hattie's Brake, has an extremely limited distribution within the state (Robison and Buchanan, *Fishes of Arkansas*, 1988).

Our appreciation is expressed to Mr. Jim Barnett, representing the owners, and to Mr. Don Colemann, who leases the land, for their cooperation in allowing us entry into the study area. The study has been supported by funds from the Natural Sciences and Mathematics Division and by a faculty development grant from Arkansas College.

Table 1. Fishes of Hattie's Brake

I. **Lepisosteidae** Gars
   - A. *Lepisosteus oculatus* (Winchell). Spotted Gar.
   - B. *Lepisosteus osseus* (Linnaeus). Longnose Gar.
   - C. *Lepisosteus platostomus* Rafinesque. Shortnose Gar.

II. **Amiidae** Bowfins
   - A. *Amia calva* Linnaeus. Bowfin.

III. **Clupeidae** Herrings
   - A. *Dorosoma cepedianum* (Lesueur). Gizzard Shad.

IV. **Esocidae** Pikes
   - A. *Esox americanus* Gmelin. Grass Pickerel.

V. **Cyprinidae** Minnows and Carps
   - A. *Campostoma anomalum* (Rafinesque). Central Stoneroller.
   - B. *Cyprinus carpio* Linnaeus. Common Carp.
   - C. *Notemigonus crysoleucas* (Mitchill). Golden Shiner.

VI. **Catostomidae** Suckers
   - A. *Carpiodes carpio* (Rafinesque). River Carpsucker.

VII. **Ictaluridae** Bullhead catfishes
   - A. *Ictalurus melas* (Rafinesque). Black Bullhead.
   - B. *Ictalurus natalis* (Lesueur). Yellow Bullhead.

VIII. **Aphredoderidae** Pirate perches
   - A. *Aphredoderus sayanus* (Gilliams). Pirate Perch.

IX. **Fundulidae** Killifishes
   - A. *Fundulus dispar* (Agassiz). Northern Starhead Topminnow.
   - B. *Fundulus notatus* (Rafinesque). Blackstripe Topminnow.
   - C. *Fundulus olivaceus* (Storer). Blackspotted Topminnow.

X. **Poeciliidae** Livebearers
   - A. *Gambusia affinis* (Baird and Girard). Mosquitofish.

XI. **Atherinidae** Silversides
   - A. *Labidesthes sicculus* (Cope). Brook Silverside.

XII. **Centrarchidae** Sunfishes
   - A. *Centrarchus macropterus* (Lacépède). Flier.
   - B. *Lepomis cyanellus* (Rafinesque). Green Sunfish.
   - C. *Lepomis gulosus* (Cuvier). Warmouth.
   - D. *Lepomis humilis* (Girard). Orangespotted Sunfish.
   - E. *Lepomis macrochirus* (Rafinesque). Bluegill.
   - F. *Lepomis megalotis* (Rafinesque). Longear Sunfish.
   - G. *Lepomis microlophus* (Gunther). Redear Sunfish.
   - H. *Lepomis punctatus* (Valenciennes). Spotted Sunfish.
   - I. *Micropterus salmoides* (Lacépède). Largemouth Bass.
   - J. *Pomoxis annularis* (Rafinesque). White Crappie.

XIII. **Elassomatidae** pygmy sunfishes
   - A. *Elassoma zonatum* (Jordan). Banded Pygmy Sunfish.

XIV. **Percidae** Perches
   - A. *Etheostoma fusiforme* (Girard). Swamp Darter.
   - B. *Etheostoma gracile* (Girard). Slough Darter.

Additional Occurrences of the Bog Clubmosses in Southern Arkansas

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Field studies by Peck et al. (1987) from 1985 until 1987 demonstrated that the bog clubmosses of southern Arkansas were represented by four distinctive species and three hybrids. Before that time all collections were identified as a single species, designated as *Lycopodium appressum* (Chapm.) Lloyd & Underwood or by the orthographic variant *L. adpressum*. This species had been reported (Smith 1978) from seven counties: Clark, Hempstead, Lafayette, Nevada, Ouachita, Saline, and Union. (We have been unable to verify the Lafayette County report.) Peck et al. (1987) added Calhoun and Garland Counties to the known range of *L. appressum*, and Smith (1988) indicated the addition of Hot Spring County. The three new species and three new hybrids were found only in Calhoun County by Peck et al. (1987). The report of these taxa in Calhoun County led to our speculation that of them might occur in clubmoss sites we had visited earlier with the presumption that only *L. appressum* occurred in our area.

The purpose of our study was to reevaluate clubmoss populations we had previously identified as *L. appressum*, and to search for new clubmoss locations. We are grateful to Mr. Don Crank for showing us a special area on the border of Hot Spring and Saline Counties, and for assisting with photography and field work. We are grateful to Mr. Carl Amason for showing us the clubmoss populations in Calhoun County, and for presenting us with copies of Snyder and Bruce's *Field Guide*.

Arkansas botanists have generally followed the traditional recognition of a broadly defined genus *Lycopodium*. Modern biosystematic studies support dividing the clubmosses into a number of more precisely defined genera. The many extensive studies of clubmoss systematics were recently summarized by Wagner and Beitel (1992), Øllgaard (1992), and Wagner (1992). Øllgaard (1992) treated all bog clubmosses which occur in our area as members of the genus *Lycopodiella* Holub, while Wagner and Beitel (1992) segregated the Carolina bog clubmoss as *Pseudolycopodiella caroliniana* (L.) Holub. In the present study we have adopted the more conservative delineation of Øllgaard. Our identifications of species and hybrids are based on keys, descriptions, and illustrations in Bruce (1975, 1976) and Snyder and Bruce (1986). Comparisons were also made with Correll and Johnston (1979). The four species recognized are *Lycopodiella appressa* (Chapman) Cranfill, *L. alopecuroides* (L.) Cranfill, *L. prostrata* (Harper) Cranfill (all in Section *Lycopodiella*) and *L. caroliniana* (L.) Pichi-Serm., isolated in Section *Caroliniana* (Bruce) B. Øllgaard. The hybrids considered are *Lycopodiella* x *copelandii* (Eiger) Cranfill (*L. alopecuroides* x *appressa*), *L.* x *bruceii* Cranfill, (*L. appressa* x *prostrata*), and *L. alopecuroides* x *prostrata*. Nomenclature is based on Cranfill (1981) and Øllgaard (1992).

The study was initiated in September 1992 when Mr. Don Crank called attention to a site northeast of Malvern, Arkansas, where clubmosses were found on each side of a road on the boundary between Hot Spring and Saline Counties. Upon initial investigation the plants appeared to represent more than one taxon, and additional trips were made for field study, photography, and collecting specimens. Each of us made a separate trip with Carl Amason and Don Crank to clubmoss sites in Calhoun County (DLM on July 5, 1992, JRB on November 7, 1992) to become familiar with *Lycopodiella alopecuroides*, *L. prostrata*, and *L. caroliniana* in the field.

In Clark County local clubmoss populations north of Arkadelphia were searched for variations. New vouchers were collected for study, and earlier specimens housed in the Henderson State University Herbarium were re-examined. *In situ* photographs were made of *L. caroliniana*. Field work was terminated in March of 1993 after winter conditions were examined. All vouchers collected during the study were deposited in the Henderson State University Herbarium.

Southern or Common Bog Clubmoss, *Lycopodiella appressa*, was found in all clubmoss communities examined, often as the predominant clubmoss present. Several local populations around ponds near Lake DeGray in Clark County were apparently pure stands of this species. Branching peduncles were often found in this species. Only simple branching is mentioned in published sources, but we found plants with up to seven branches. Two to four branches were most common. In several sites scattered plants were found with conspicuously twisted peduncles. These plants otherwise appeared as normal *L. appressa*. Twisting of peduncles seems to correlate with site conditions, since this has been observed only in plants growing up through dead tree branches or dense growths of grass. Strobilus length was quite variable within most populations, ranging from approximately 4 to 12 cm.

Foxtail Clubmoss, *Lycopodiella alopecuroides*, was found

Additional Occurrences of the Bog Clubmosses in Southern Arkansas

in several local populations between Malvern and Traskwood in Saline and Hot Spring counties. One restricted population was found in Clark County. In one of the Saline County sites the peduncles were particularly large, one measuring 52 cm in height. All local populations observed were more restricted than that usually seen in *L. appressa*, but *L. alopecuroides* was the predominant clubmoss in two Saline County sites. *L.* x *copelandii* (*L. alopecuroides* x *appressa*), occuring in Saline and Clark Counties, was the only hybrid found thus far outside Calhoun County. An herbarium specimen collected from the Clark County site on October 15, 1986 (Watson 29), has a strobilus which forks near the middle, a condition which we have not seen elsewhere.

Creeping Foxtail Clubmoss, *Lycopodiella prostrata*, was found in one Saline County site with *L. appressa*. The smaller prostrate main stems were distinctive from those of nearby *L. alopecuroides* populations. Outside Calhoun County we have found only one site for *Lycopodiella prostrata* and have not yet positively identified its hybrids. We believe this probably represents lack of searching rather than lack of occurrence.

We were particularly gratified to find a relatively large population of Slender Clubmoss, *Lycopodiella caroliniana*, in Clark County north of Arkadelphia, since it seems to be very rare and threatened in Calhoun County. Although its abundance is not comparable with *L. appressa* in the same site, there were hundreds of individuals present, making it by far the largest population of *L. caroliniana* we have seen. The bog clubmoss community was dominated by *L. appressa*, but *L. caroliniana* was considerably more abundant than *L. alopecuroides* and *L.* x *copelandii*. One Slender Clubmoss plant was found with a branched peduncle.

The most common associates of the bog clubmosses found were *Xyris* species (*X. jubicai*, *X. iridifolia*, and perhaps others). This genus was found in virtually all sites. *Sphagnum* is often found in the wetter sites. *Drosera brevifolia* is a frequent associate in Calhoun, Hot Spring, and Saline Counties. Although this species occurs in Clark County, we have not yet seen it with clubmosses. During the winter the clubmoss peduncles died but often remained standing. Horizontal stems and their leaves remained mostly green.

Our study indicates a greater degree and frequency of peduncle branching than indicated in the literautre. Øllgaard (1992) described the peduncles in Section *Lycopodiella* as simple or up to twice-forked. Those of Section *Caroliniana* are described as simple. Bruce (1975) described the peduncle of *Lycopodiella caroliniana* as unbranched. Snyder and Bruce (1986) described the peduncles of all the bog clubmosses as unbranched. We have found nothing on branching of strobili.

We have learned that bog clubmoss communities in Arkansas previously thought to contain only *Lycopodiella appressa* often include one or more additional species. These sympatric occurrences in Clark, Hot Spring, and Saline Counties are comparable to that found in Calhoun County by Peck et al. (1987). Some sites examined in Clark County early in this study were thought to have extensive pure stands of *L. appressa*, but these should be searched more carefully. We now believe the sympatric occurrences of several bog clubmoss species described by Bruce (1975) are more likely overlooked than remarkable in southern Arkansas.

Literature Cited

Bruce, J.G. 1975. Systematics and morphology of sub genus *Lepidotus* of the genus *Lycopodium* (Lycopodiaceae). Ph. D. dissertation, University of Michigan, Ann Arbor, MI. (Univ. Microfilms Intern. 76-9355).

Bruce, J.G. 1976. Comparative studies in the biology of *Lycopodium carolinianum*. Amer. Fern J. 66(4) :125-137.

Correll, D.S. and **M.C. Johnston.** 1979. Manual of the Vascular Plants of Texas. Univers. of Texas at Dallas, Richardson.

Cranfill, R. 1981. Bog clubmosses (*Lycopodiella*) in Kentucky. Amer. Fern J. 71(4) :97-100.

Øllgaard, B. 1992. Neotropical Lycopodiaceae–an overview. Ann. Missouri Bot. Gard. 79(3) :687-717.

Peck, J.H., C.J. Peck, S.L. Orzell, E. Bridges, and **C. Amason.** 1987. Discovery of *Lycopodium* communities in the Gulf Coastal Plain region of Arkansas. Proc. Ark. Acad. Sci. 41:112-113.

Smith, E.B. 1978. An atlas and annotated list of the vascular plants of Arkansas. Published by the author.

Smith, E.B. 1988. An atlas and annotated list of the vascular plants of Arkansas, 2nd ed. Published by the author.

Snyder, L.H. and **J.G. Bruce.** 1986. Field guide to the ferns and other pteridophytes of Georgia. Univ. of Ga. Press, Athens. 270 pp.

Wagner, F.S. 1992. Cytological problems in *Lycopodium* sens. lat. Ann. Missouri Bot. Gard. 79(3) :718-729.

Wagner, W.H., and **J.M. Beitel.** 1992. Generic classification of modern North American Lycopodiaceae. Ann. Missouri Bot. Gard. 79(3) :676-686.

New Distributional Records for Arkansas Surgeons

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Of the three species of sturgeons known to occur in Arkansas, only the shovelnose sturgeon, *Scaphirhynchus platorynchus* (Rafinesque), is common in the state (Robison and Buchanan, *Fishes of Arkansas*, Univ. Arkansas Press, Fayetteville, 1988). Prior to 1988 only three records for the lake sturgeon, *Acipenser fulvescens* Rafinesque, were known from Arkansas; two records were reported for the pallid sturgeon, *Scaphirhynchus albus* (Forbes and Richardson). The two *S. albus* records were based on reports from commercial fishermen who provided accurate descriptions of this species, but no vouchered specimens were available from the state. Robison and Buchanan (loc. cit) also included *S. albus* in Arkansas' ichthyofauna because of valid records from the Mississippi River of Missouri and Louisiana.

An increase in the sturgeon fishery of Arkansas in the last few years has resulted in more reports of a large white sturgeon (6.8 kg or more) by commercial fishermen. These reports, which occur during the peak of the sturgeon spawning run from early March to mid April, come mainly from the Mississippi River and more rarely from the lower White River. We report the first vouchered record in Arkansas of *S. albus* and two new records for *A. fulvescens*. The two new records for *A. fulvescens* are the first from the White River. On 19 May 1989, a 1245 mm TL, 3.63 kg female *A. fulvescens* was caught by a commercial fisherman in the White River, Desha County. It was caught in a trammel net fished in the eddy of the junction of the two rivers. The specimen was freeze-dried and is on display in the Westark Community College fish collection. On 29 April 1992, one of us (K. S.) examined a live lake sturgeon at Prince's Fish Market in Brasfield, Arkansas. It was approximately 1524 mm TL (not measured), weighed 21.34 kg, and was caught in late March 1992 by Mr. A. D. Adcock in the White River at Devalls Bluff, Prairie County. This specimen was subsequently released into the White River.

The first vouchered record of *S. albus* for Arkansas was taken in April 1988 (exact date not known) from the Mississippi River at Mile 665 near Helena, Phillips County, by a commercial fisherman using a trotline baited with worms. It was 1090 mm TL, weighed 3.75 kg, and conformed completely in morphological and meristic features to *S. albus;* i.e., the belly was naked, the bases of the outer barbels were situated 5 mm posterior to the bases of the inner barbels, and it had 37 dorsal rays and 25 anal rays. This freeze-dried specimen is also on display at Westark Community College.

Sturgeons are among the poorest known Arkansas fishes because of the difficulty of collecting in their big river habitat and the rarity in the state of two of the three species. The shovelnose sturgeon, *S. platorynchus*, currently supports a commercial fishery in the Mississippi and lower White rivers and is not endangered or threatedned at this time. However, we recommend that *S. albus* and *A. fulvescens* be categorized as endangered in Arkansas because of their apparent rarity.

Rapid Reduction of Nitrate Ion In Rain Water

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In the past 10 years, there have been numerous studies of the effect of delayed analysis or storage before analysis on the measured concentrations of several chemical species found in precipitation, with the major emphasis on the changes in free acidity (Galloway and Likens, 1976; Madsen, 1982; Keene and Galloway, 1984; de Pena et al., 1985; Mahendrappa, 1985; Sisterson et al., 1985; Chan et al., 1987; Tang et al., 1987; Bigelow et al., 1989). Only two of these reports identify the consumption of nitrogen (N) species as a significant problem associated with samples that had been stored for some time before nitrate [N(V)] analysis. Mahendrappa (1985) compared nitrate analyses of rainwater performed upon collection with those performed on samples after cold storage and on samples that were stored in the field. Storage time was as long as a month. Decreases in nitrate concentration as large as 50% were observed during storage. In a study comparing event samples with weekly samples, de Pena et al. (1985) found an average 14% decrease in nitrate in the time period between the event and the collection of weekly samples.

Alteration of pH has most often been attributed to dissolution and reaction of basic compounds contained in suspended solids or to the microbial oxidation of organic acid anions. It is possible that alteration of nitrate concentration may be attributable to microbial reduction also.

Michaelis-Menten (pseudo-zero order) kinetics are observed in most cases of the bacterial reduction of N(V) in soil. However, when concentrations of substrates are so low as not to saturate the enzyme, the reaction is first order in N(V) (Bowman and Focht, 1974).

The reduction of N(V) in rainwater may be connected to the reduction of N(V) in soils. The association of metal ions in rainwater with agricultural/soil sources has been confirmed by the PCA analysis of wet deposition (Hooper and Peters, 1989). Abnormally high concentrations of metal ions may be an indication of the inclusion of soil or soil water components into rainwater.

This laboratory studied 62 rainfalls that occurred in the 19 month period beginning in January, 1987. The original purpose of this study was to examine the dilution effect of rainout on the major ionic species found in rainfall and the relationships between these species. During this study, 7 samples were observed in which a significant reduction of nitrate ion occured in a storage period of days rather than weeks. Rates of loss were greater than those cited above by more than an order of magnitude. These rapid losses have implications for the interpretation of N(V) concentrations in rainwater. It is the purpose of this report to bring to the attention of investigators of within-event precipitation chemistry the possibility of nitrate loss in fractions taken early in a rainfall.

The sampling site was in a residential area of the central region of Jonesboro, Arkansas, a city of 48,000 surrounded by agricultural land. The collector was located at the center of a 12 m x 9 m area free of overhead obstacles. There was no problem with wind carried debris except when wind velocity exceeded 40 km h^{-1}, conditions that did not occur during any of the events described below. Nor was the problem of rainwater rebounding from trees or structures ever observed.

The rainwater was collected using a 25 cm diameter polyethylene funnel placed at a height of approximately 1 m above the ground. The rainwater was immediately transferred to a 250 mL polyethylene bottle. For each event described herein, the funnel was washed to remove dry precipitate usually immediately before the rain event began but no longer than 5 h before the onset of rainfall so that contamination from this source was minimized.

Rainwater was collected as sequential fractions within each event. A small aliquot was taken for pH measurement and the rest immediately refrigerated at 5°C. Generally, each fraction was equivalent to 2 – 6 mm of rainfall.

Within 24 h of collection all samples were filtered through a pre-weighed 0.45 µm membrane filter. For the 1988 samples, a fiberglass prefilter was used in addition to the membrane filter. Since there was, initially, no expectation of observing any reduction of N(V), the sample bottles were used as storage containers after being cursorily washed to remove any adhering solids, rinsed with distilled water, and drained. The filtrate was returned to that bottle and placed back in refrigeration at 5°C until the initial anion analysis was completed. This cursory washing of the sample bottles, without sterilization, may have led to the discovery of the effect described herein since trace catalysts adhering to the walls may have a part in this effect.

All analyses reported in this study, except those done by ion chromatography (IC), were performed according to standard methods (Franson, 1980). Analyses of the

concentrations of the nitrate and nitrite ions were performed by the cadmium reduction method and/or IC using Varian a 5000 liquid chromatograph equipped with a Wescan 269-001 anion column and using an elutant of 1 mM phthalic acid adjusted to a pH of 4.8 to 5.0. A UV detector at 250 μm was used. The pH was determined using a glass electrode. The metal ions were determined using atomic adsorption (AA).

The IC and the spectrometers were recalibrated after every 8 to 10 samples. Samples spiked with standard solution were regularly analyzed. The average percent recovery of the spike in N(V) samples was 96.8% for the samples described herein; for the metal ions, recovery averaged 98%.

In 1988 care was taken to examine samples of high solids content and high metal ion concentration for the presence of N(III) and/or significant decreases of N(V) with time from collection. Concentrations of the N species were determined within hours of collection and again 11 to 28 days later.

The rainwater samples discussed here constitute a subset of a total of 288 fractions collected from 62 rain events sampled between January, 1987 and July, 1988. In the period from February, 1987 to July, 1988, 94 fractions from 23 rainfalls were analyzed for N(V) at two different times. Five of the 23 rainfalls yielded 7 atypical samples, i.e. fractions which exhibited a rapid decrease in N(V) concentration (Table 1).

Table 1. Analyses of Precipitation Samples Exhibiting a Detectable Reduction of N(V) during Storage, 1987-1988, and the volume weighted average (VWA) for the first fraction of all rainfall samples. The concentration of all ions is given in μequ L^{-1}.

Sample	VWA	14-1	14-2	27-1	27-3	57-1	58-1	59-1
Date Collected		870503	870503	870910	870910	880417	880503	880513
Date, Analysis 1		870504	870505	870927	870927	880422	880516	880516
Date, Analysis 2		870505	870506	880105	880105	880503	880527	880527
Solids (mg/L)	20	103	37	9.2	25.2	<2.0	69	53
pH, Analysis 1	4.00	4.78	4.49	3.91	3.35	3.92	---	5.26
pH, Analysis 2		---	---	---	---	4.20	5.29	5.44
N(V), Analysis 1	80	110	26	64.3	38.9	36	61	200
N(V), Analysis 2		69	19	2.1	1.4	26	<1	169
NH_4^+	34	---	---	<3	59	103	53	96
K+	30	223	394	37	2.8	7.3	330	46.3
Metal Cations	153	732	642	373	43.6	77.3	566	440
K+/Na+	1.0	1.1	2.7	1.1	0.48	0.24	8.5	0.50
Estimated k (d^{-1}) at 22°C		0.741*#	0.32*	0.034	0.033	0.030	>0.45	0.015

* = at 5°C # = determined from five data points – = not determined

Five of the atypical samples were the first fractions collected from the rain event. In the 3 atypical samples in which the rate constant (k) for the reduction was greater than 0.3 d^{-1}, the concentrations of solids, total metal cations (Na, K, Ca, and Mg), and K/Na, were significantly greater than the volume weighted average concentrations of those species in all 62 first fractions.

Of these atypical samples, the most notable and the most thoroughly studied was the first fraction from the fourteenth rainfall sampled (designated 14-1), collected on 5 May 1987 (designated here as 870505). For this sample, IC analyses for N(V) were performed on each of the four days subsequent to collection, revealing that the amount of nitrate ion was decreasing rapidly with time. The decrease in the concentration of N(V) with time since collection for sample 14-1 is illustrated in Fig. 1, along with the best fit line determined by regression analysis. The regression analysis of the data for fraction 14-1 indicates that the ln C plot provides the best fit (R^2=95.0%), suggesting first order kinetics which is expected for the reduction of N(V). The rate constant is (0.741 ± 0.098) d^{-1}. The rate constant for sample 14-2 was estimated from two points to be 0.32 d^{-1}, smaller but still indicative of rapid reduction. These values are all the more striking since both samples were stored at 5°C from the time of collection.

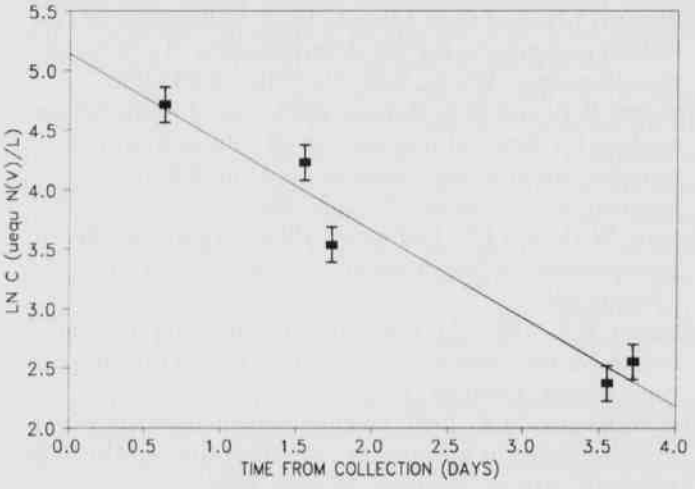

Fig. 1. Concentration of N(V) as a Function of Time from the Collection of Sample 14.1.

The other five samples were stored at 22°C between analyses. Their first order rate constants for disappearance of N(V) were also estimated from just two time separated concentration measurements. The rate constants ranged between 0.015 and >0.45 d^{-1}. In contrast, the mean rate constants for typical samples was 0.004 d^{-1}.

A study of the conditions under which nitrate ion

becomes an oxidizing agent in rainwater is warranted by these findings.

The author wishes to thank the Research Fund of Arkansas State University for the partial funding of this project.

Literature Cited

Bigelow, D.S., D.L. Sisterson and **L.J. Schroder.** 1989. An interpretation of differences between field and laboratory pH Program/National Trends Network Monitoring Program. Environ. Sci. Technol. 23:881-887.

Bowman, R.A. and **D.D. Focht.** 1974. The influence of glucose and nitrate concentrations upon denitrification rates in sandy soils. Soil Biol. Biochem. 6:297-301.

Chan, W.H., A.J.S. Tang, D.H.S. Chung and **N.W. Reid.** 1987. An analysis of precipitation chemistry measurements in Ontario. Environ. Sci. Technol. 21:1219-1224.

de Pena, R.G, K.C. Walker, L. Lebowitz and **J.G. Micka.** 1985. Wet depostition monitoring - effect of sampling period. Atmos. Environ. 19:151-156.

Franson, M.A.H., managing editor: 1980, Standard Methods for the Examination of Water and Wastewater, 15th ed., APHA-AWWA-WPCF, Washington, D.C., 1134 pp.

Galloway, J.N. and **G.E. Likens.** 1976. Calibration of collection procedures for the determination of precipitation chemistry. Water, Soil, Air Pollut. 6:241-258.

Hooper, R.P. and **N.E. Peters.** 1989. Use of multivariate analysis for determining sources of solutes found in wet atmospheric deposition in the United States. Environ. Sci. Technol. 23:1263-1268.

Keene, W.C. and **J.N. Galloway.** 1984. Organic acidity in precipitation of North America. Atmos. Environ. 18:2491-2497.

Madsen, B.C. 1982. An evaluation of sampling interval length on the chemical composition of wet-only deposition. Atmos. Environ. 16:2515-2519.

Mahendrappa, M.K. 1985. Precipitation chemistry affected by differences in location of collection sites and storage methods. Atmos. Environ. 19:1681-1684.

Sisterson, D.L., B.E. Wurfel and **B.N. Lesht.** 1985. Chemical differences between event and weekly precipitation samples in northeastern Illinois. Atmos. Environ. 19:1453-1469.

Tang, A.J.S., W.H. Chan, D.B.Orr, W.S. Bardswick and **M.A. Lusis.** 1987. An evaluation of the precision, and various sources of error, in daily and cumulative precipitation chemistry sampling. Water, Soil, Air Pollut. 36:91-102.

Suppression of the Oxidation of S(IV) in Rain Water

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The combustion of fossil fuels containing sulfur compounds injects SO_2 [S(IV)] into the troposphere. The most stable oxidation state of combined sulfur under aerobic conditions is S(VI). S(IV) is rapidly oxidized, principally by the OH radical, in aerosols, clouds, or individual rain droplets. Oxidation rates of S(IV) as high as 30% h^{-1} have been observed (Finlayson-Pitts and Pitts, 1986). Although the presence of organics and transition metal ions can promote higher concentrations of S(IV) in aerosols, clouds, and rain droplets than would be expected from equilibrium considerations (Huie and Peterson, 1983; Eatough and Hanson, 1983), one would normally expect to find very high S(VI)/S(IV) ratios in rainwater.

However the presence of aldehydes, particularly HCHO, can result in the slow formation of S(IV) adducts that are stable toward oxidation (Munger et al., 1984). Under such conditions, S(IV) may have concentrations above the limit of detectibility.

Should reducing conditions prevail in isolated regions of a water sample, the S(VI) may be reduced. It is known from the study of soil waters that bacterial reduction is possible in localized anaerobic regions of waterlogged soils (Greenland and Hayes, 1981). However, the product of the reduction is S(-II) rather than S(IV). Thus, if significant amounts of S(IV) are observed in a rainwater sample, it is probably due to a decrease in the rate of oxidation of S(IV).

The rainfall sampling site was in a residential area of the central part of the city of Jonesboro, Arkansas. The collector was located at the center of a 100 m^2 area free of overhead obstacles. Tree and structure density in the surrounding area was typical of an older residential section. There was no problem with wind carried debris except when wind velocity exceeded 40 km h^{-1} nor was the problem of rainwater rebounding from trees or structures ever observed.

The rainwater was collected using a 25 cm diameter polycarbonate funnel placed at a height of approximately 1 m above the ground. The rainwater was immediately transferred to a 250 mL polyethylene bottle. For the event described herein, the collector was washed to remove dry precipitate within 5 h of the onset of rainfall so that contamination from this source was minimized.

Rainwater was collected as sequential fractions within each event. The fractions were equivalent to 2-6 mm of rainfall. Immediately upon collection, the pH of all water samples was determined, and the water was stored in polycarbonate bottles and refrigerated at 5°C.

Within 24 h of collection the rainfall samples were filtered through a pre-weighed combination of Whatman 40 paper and 0.45 µm membrane filter. The filtrate was returned to that bottle and placed back in refrigeration until anion analysis was completed.

Analysis of the concentrations of the major anions was performed using a Varian 5000 liquid chromatograph equipped with a Wescan 269-001 anion column and using an elutant of 1mM phthalic acid adjusted to a pH of 4.8-5.0. The presence of nitrite ion was confirmed by using the standard sulfanilamide-NED colorimetric method (Franzen, 1980). The mass of suspended solids was determined by weighing the filters after drying in air and then a desiccator. Other species were also determined by standard methods: phosphate by the ascorbic acid method; and the major metal cations by atomic absorption.

This report deals only with the rainfall of 13 April 1987. All but the last of the five fractions collected during this rainfall were noticeably colored by the inclusion of large amounts of soil-like solids. The color varied from the first fraction's deep tan to the fourth's faint yellow. The first fraction, after filtration and sitting for ten days, became cloudy and then a fibrous precipitate formed. The analyses for this fraction were quite unusual with very high concentrations of solids and the phosphate and K(I) ions.

The ion chromatogram of the first fraction, summarized in Table 1 (where RT = retention time of the anion and α = separation factor of the anion with respect to sulfate), exhibited a peak not observed in any of the 283 samples from 61 other events studied during this time. Neither did this peak (peak 3 in Table 1) appear in chromatograms of later fractions. This peak has been attributed to sulfite ion on the basis of its α value which corresponds well to that found for a solution of $NaHSO_3$. The α value in question does not come close to those of the anions commonly found in rainwater.

A third peak (peak 2), rarely observed in 62 rainfalls, was tentatively identified from its α value as due to the nitrite ion. The presence of nitrite was confirmed by colorimetric analysis. By that time, however, the nitrite concentration had decreased to 4 µequiv/L. The initial con-

centration was estimated to have been approximately 150 μequiv/L using a standard chromatogram of nitrite ion run eleven days after the fraction's chromatogram. Neither the first or second fraction contained any nitrate ion.

Table 1. Summary of retention times (RT) and separation factors (α) of peaks in sample and standard chromatograms.

Peak No.	13 Apr Sample RT (min)	α	April Standard RT (min)	α	Sulfite Standard RT (min)	α
1 (cl)	2.012 ±.001	0.187 ±.001	2.074 ±.004	0.199 ±.002		
2 (NO_2)	2.368 ±.004	0.253 ±.001	2.398 ±.001	0.259 ±.002		
3 ($SO_3^=$)	5.610 ±.021	0.848 ±.003			7.731 ±.025	0.833 ±.006
4 ($SO_4^=$)	6.447 ±.015	----	6.431 ±.021	----	9.083 ±.018	----
Solvent	0.991 ±.001	----	0.992 ±.006	----	0.984 ±.006	----
NO_3			2.627 ±.010	0.301 ±.003		

It is hypothesized that rainwater samples from this event incorporated significant amounts of airborne soil during aerosol or droplet formation. The airborne soil may have been a result of the preparation of agricultural fields for Spring planting. The coloration due to soil-like solids and the presence of high concentrations of ions found in commercial fertilizers support this inference (Hooper and Peters, 1989).

Since S(IV) cannot be the product of the reduction of S(VI), it must be concluded that the oxidation of S(IV) that had dissolved in the aerosol or droplets after their formation was suppressed by the presence of large amounts of soil and the organic material associated with it. The S(VI) observed probably resulted from the incorporation of particulate metallic sulfates during droplet formation.

However, the incorporation of metallic nitrates would also be expected. But it is possible that any N(V) initially present was consumed before the analysis. Nitrate has been observed to be consumed by reduction in rain water (Mahendrappa, 1985; de Pena et al., 1985); N(III) is an intermediate in this process.

It is also of interest to note the co-existence of N(III) and S(IV). In aqueous solutions containing only these species, the N(III) would be reduced to N(-III) while S(VI) would be formed. The reducing conditions induced by the presence of the soil carried impurities stabilized the N(III) and S(IV).

Thus, it is believed that a rare occurrence (in 1 out of 62 events sampled), the interrupted oxidation of S(IV) to S(VI), was observed in this 13 April 1987 sample which contained large amounts of soil and organic matter.

The author wishes to thank the Research Fund of Arkansas State University for the partial funding of this project.

Literature Cited

de Pena, R.G., K.C. Walker, L. Lebowitz and **J.G. Micka.** 1985. Wet deposition monitoring - effect of sampling period. Atmos. Environ. 19:151-156.

Eatough, D.J. and **L.D. Hansen.** 1983. Organic and inorganic S(IV) compounds in airborne particulate matter, Adv. Environ. Sci. Technol. 12:221-268.

Finlayson-Pitts, B.J. and **J.N. Pitts.** 1986. Atmospheric chemistry. John Wiley and Sons, New York, 1098 pp.

Franson, M.A.H. 1980. Standard Methods for the Examination of Water and Wastewater, 15th ed. APHA-AWWA-WPCF, Washington, D.C., 1134 pp.

Greenland, D.J. and **M.H.B. Hayes.** 1981. The chemistry of soil processes. John Wiley and Sons, New York, 714 pp.

Hooper, R.P. and **N.E. Peters.** 1989. Use of multivariate analysis for determining sources of solutes found in wet atmospheric deposition in the United States. Environ. Sci. Technol. 23:1263-1268.

Huie, R.E. and **N.C. Peterson.** 1983. Reactions of sulfur (IV) with transition-metal ions in aqueous solutions, Adv. Environ. Sci. Technol. 12:117-126.

Mahendrappa, M.K. 1985. Precipitation chemistry affected by differences in location of collection sites and storage methods. Atmos. Environ. 19:1681-1684.

Munger, J.W., D.J. Jacob and **M. Hoffmann.** 1984. The occurrence of bisulfite-aldehyde addition products in fog- and cloudwater, J. Atmos. Chem. 1:335-350.

Microscale Preparation of Pyrocatechol: The Use of Sodium Percarbonate in the Dakin Reaction

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Sodium percarbonate (Na_2CO_3 $3/2H_2O_2$), a common household detergent, is an inexpensive, stable, and easily handled reagent that has an excellent shelf life. One equivalent of sodium percarbonate releases one and one-half equivalents of hydrogen peroxide. Sodium percarbonate (Fig. 1) has been used for the oxidation of sulfides (Ando, Chem. Lett., 665, 1986), amines (Zazac, J. Org. Chem., 54:2468, 1988), and organoboranes (Kabalka, Organometallics, 9:1316,1990). We wish to report the use of this reagent for the preparation of pyrocatechol from salicylaldehyde (Yamazaki, M.S. Thesis, University of Arkansas at Little Rock, 1991), a Baeyer-Villiger type reaction commonly referred to as the Dakin reaction (Dakin, Org. Synth., Coll. Vol. 1: 149-150, 1964).

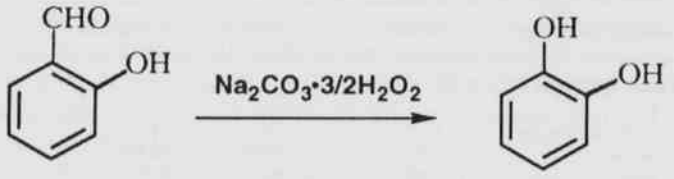

Fig. 1. Sodium percarbonate

To a solution of salicylaldehyde (244 mg, 2 mmol) in 3 ml of 1 N sodium hydroxide was added gradually sodium percarbonate (630 mg. 6 mmol). A vigorous exothermic reaction occurred immediately with darkening of the mixture which was then stirred for 24 hours in a sandbath at 50°C. After chilling the reaction mixture in an ice-bath and neutralization with acetic acid, the solvent was completely removed under reduced pressure leaving a dry black residue. The residue was finely crushed and extracted with toluene overnight using a microscale Soxhlet extraction apparatus. The toluene solution was evaporated to yield crude pyrocatechol which was further recrystallized from toluene to afford 0.11 g of pure compound in 50% yield, mp 102-104°C (Lit. 105°C).

Similarly, pyrocatechol was also obtained from 2-hydroxyacetophenone in 69% yield. In closely related experiments, hydroquinone was prepared from 4-hydroxybenzaldehyde in 35% yield as well as from 4-hydroxyacetophenone in 66% yield (Evans, M.S. Thesis, University of Arkansas at Little Rock, 1991). In all cases the ir and nmr spectra of the products were identical to those of authentic samples.

Acknowledgements

We thank UALR Cooperative Research Fund for partial support of the work.

Quality of Shrimp Available to Consumers in Arkansas

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The Food and Drug Administration (FDA) has not set standards for the bacteriological and chemical quality of fresh shrimp sold by retailers, but it is currently developing the criteria and methods needed for such evaluation (Sloan and Hagen, 1992). These efforts have resulted from national attention being focused on seafood quality and the dangerous lack of regulation in the seafood industry. However, several published studies have suggested acceptable levels of bacterial and chemical parameters to be used in determining seafood quality (Cobb and Vanderzant, 1975; Matches, 1982; Shamshad et al., 1990). This study utilizes these recommendations in investigating the quality of "fresh" shrimp available to Arkansas consumers.

Quantities of shrimp (454 g) were purchased from retail outlets throughout the state. After transport (30-45 min) to the laboratory on ice, the tail, shell and exposed anterior tissue were removed and discarded. The remaining muscle tissue was divided into 10 g (wet weight) amounts and held at approx. 20°C until analyses were carried out on the same day.

Total aerobic bacteria were enumerated from a homogenate of 10 g of shrimp and 90 ml diluent (0.1% Bacto Peptone, 0.9% NaCl) by spread plating on tryptone soy agar (Difco). All colony forming units (cfu) were counted after 48 h incubation at 25°C (Shamshad et al., 1990). Triplicate counts were performed on each sample and a mean determined. Plates with more than 200 cfu were recorded as too numerous to count (TNTC).

The pH was determined for homogenate of 10 g of shrimp and 20 ml of chilled (4°C) distilled, sterilized water (Shamshad et al., 1990). Two measurements were performed and the median recorded for each sample.

Retail vendors tended to display shrimp either frozen (approx. 20°C), or on ice (approx. 0°C), or refrigerated (approx. 10°C). For analysis, the date were grouped accordingly.

Shamshad et al. (1990) determined a mean number of bacteria for fresh shrimp to be 5.0×10^5 cfu/g. Increases in bacterial counts were proportional to storage time and temperature, reaching 3.5×10^7 cfu/g after 16 days at 0°C which was recommended as the limit of acceptability for human consumption. Acceptable limits for bacterial numbers have not been determined by the FDA (Sloan and Hagen, 1992), but elevated levels in sea water and other shellfish (oysters, clams, muscles and crabs) have been declared a health hazard (FDA Compliance Policy Guides #7108.25 and #7119.12, 1989).

Of the 34 samples analyzed during this study, only 12 (35%) were found to be below the suggested upper limit for total aerobic bacteria (Table 1). The best quality was found for shrimp kept uniformly frozen. Six of nine frozen samples (66.7%) were found to be below the acceptable limit suggested for total bacteria. Shrimp held on ice decreased considerably in quality compared to those frozen. Only five of 13 samples (38.5%) were suitable for consumption. Refrigeration appeared to be the most inadequate in maintaining quality, since only one of twelve samples (8.3%) was below the recommended limit for bacterial numbers.

Table 1. Bacterial and chemical quality of fresh shrimp.

Commercial Display:	Frozen	On Ice	Refrigeration
Total Bacteria (cfu x 10^7/g)			
Number of Samples	9	13	12
Mean	2.97	5.97	12.29
S.D.	3.08	5.03	6.78
High	11.00	19.50	28.00
Low	1.10	1.20	2.00
% Samples Acceptable*	66.7%	38.5%	8.3%
pH Value			
Number of Samples	3	4	6
Mean	7.40	7.42	7.99
S.D.	0.19	0.15	0.41
High	7.60	7.59	8.38
Low	7.24	7.25	7.27
% Samples Acceptable+	100.0%	100.0%	16.7%

* As proposed by Shamshad et al. (1990)
\+ As proposed by Cobb and Vanderzant (1975)

The relationship between pH and sensory acceptability of shrimp was noted by both Shamshad et al. (1990), and Cobb and Vanderzant (1975). The initial pH of fresh shrimp increased proportionally with storage time and temperature. The acceptable pH values of fresh shrimp were from 7.05 to 7.60 (Cobb and Vanderzant, 1975). Once the pH exceeded 7.60, shrimp were rated as spoiled or unfit for consumption. Accordingly, the sweet, fishy

smell becomes a disagreeable, putrid odor and the once firm flesh deteriorates into a mushy or grainy textured mass. Fourteen samples were tested for pH. Only nine had pH values within the recommended limits (Table 1). The majority of these acceptable samples were purchased from retailers who kept the shrimp uniformly frozen (100%) or on ice (100%). The poorest quality samples were displayed in the open refrigeration section of the meat department. Only one of six samples (16.9%) kept in the refrigerator section had an acceptable pH value.

Although temperature was considered the significant variable in this study, time from harvest is another obvious variable which would affect quality. Fresh shrimp decompose to a point considered unsuitable in a matter of days, even when kept frozen. Matches (1982) determined that frozen shrimp will become unfit for consumption in as little as 11 days after being harvested. However, information regarding time from harvest was unattainable form most of the retailers.

The study indicated a need for regulation of storage temperature at or below 0°C until the product reaches the consumer. Excessive numbers of bacteria are considered unacceptable, but do not always indicate spoilage. However, high bacterial counts in combination with high pH values suggest that product has lost some of its quality and may not be suitable for human consumption. This study indicated, in contrast to Shamshad et al. (1990), and Matches (1982), and Cobb and Vanderzant (1975), that pH and bacterial number as measurements of quality did not always agree. Only 25% of the samples had acceptable bacterial numbers, but 64% of the samples had an acceptable pH. According to the literature, the percentage of acceptable samples in terms of bacteria counts and pH should be nearly the same.

Results of this study indicated that the consumer has only about one chance in four of buying "fresh" shrimp in Arkansas. However, until the FDA established guidelines for quality, these contaminated and possibly dangerous products will remain on the market.

Acknowledgements

This research was partially funded by a grant from Henderson State University. I am especially grateful to Ms. Edna Sloan and Mr. Kurt Hagen of the Department of Health and Human Services, Denver, Colorado for their personal communication and assistance.

Literature Cited

Cobb III, B.F., and **C. Vanderzant.** 1975. Development of a Chemical Test for Shrimp Quality J. Food Science. 40:121.

FDA Compliance Policy Guides. 1989. Chapter 8 - Fish and Seafood. Guide 7108.25.

FDA Compliance Policy Guides. 1989. Chapter 8 - Fish and Seafood. Guide 7119.12.

Matches, J.R. 1982. Effects of Temperature on the Decomposition of Pacific Coast Shrimp (*Pandalus jordani*). J. Food Science. 47:1044.

Shamshad, S.I., Kher-Un-Nisa, R. Zuberi and **R.B. Quadri.** 1990. Shelf Life of Shrimp (*Penaeus merguiensis*) Stored at Different Temperatures./J. Food Science. 55(5):1201.

Sloan, E. and **K. Hagen.** 1992. Personal Communications. Department of Health and Human Services. Denver, CO.

The S-H Stretching Frequencies in Ruthenium Mercaptan Complexes and the Crystal and Molecular Structures of $[CpRu(PPh_3)_2(s\text{-}C_4H_9SH)]BF_4 \cdot CH_2Cl_2$ and $[CpRu(PPh_3)_2(i\text{-}C_4H_9SH)]BF_4 \cdot {}^1/_2CH_2Cl_2$.

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The S-H IR stretching frequency appears as a weak absorption between 2600 and 2400 cm^{-1}. With the advent of Fourier Transform Infrared spectrophotometers, the researcher is better able to observe this resonance. To examine the effect of coordination on the S-H stretching frequencies of organic thiols, we have prepared a series of Ru-mercaptan complexes of the general formula $[CpRu(PPh_3)_2(RSH)]BF_4$, where R = n-propyl, isopropyl, -CH_2CH_2SH, n-butyl, isobutyl, and s-butyl. The crystal structures of the s-butyl- and isobutylthiol complexes, $[CpRu(PPh_3)_2(s\text{-}C_4H_9SH)]BF_4$ and $[CpRu(PPh_3)_2(i\text{-}C_4H_9SH)]BF_4$ will also be presented.

The general synthesis of the $[CpRu(PPh_3)_2(RSH)]BF_4$ complexes follows. A 0.2120 g (0.29 mmol) sample of $CpRu(PPh_3)_2Cl$ was dissolved in 30 mL of CH_2Cl_2 and 5 mL of the thiol was added. In a darkened room, excess (0.1 g, 0.5 mmol) $AgBF_4$ was added to the solution while stirring. After 15 min., the solution was concentrated to dryness under vacuum. The yellow material was dissolved in 20 mL of CH_2Cl_2 and the solution was filtered through Celite (Aldrich Chemical Company, cat. no. 16,743-6). The filtrate was concentrated to dryness, and the residue after recrystallization from CH_2Cl_2/hexanes gave a yellow microcrystalline product.

The Ru-mercaptan complexes are moisture sensitive, even in the solid state. All six compounds were characterized by single crystal X-ray diffraction studies. The isopropyl and ethanedithiol complexes were crystallographically disordered and were characterized by elemental analysis and ^1H NMR, respectively. The n-butyl compound gave poor quality crystals, but refinement showed atom connectivity in the complex (R = 0.13).

The structure of the $[CpRu(PPh_3)_2(s\text{-}C_4H_9SH)]BF_4$, *1*, complex was determined by X-ray diffraction techniques: triclinic space group $P\bar{1}$, a = 13.229 (3), b = 13.213 (8), c = 14.717 (6) Å, α = 66.87 (4), β = 84.24 (3), γ = 69.86 (4)°, Z = 2, R = 0.048, R_w = 0.061. The $[CpRu(PPh_3)_2(i\text{-}C_4H_9SH)]BF_4$, 2, complex crystallized in the triclinic space group $P\bar{1}$, a = 14.029 (6), b = 14.323 (8), c = 12.245 (4) Å, α = 69.43 (3), β = 84.35 (3), γ = 98.23 (4)°, Z = 2, R = 0.049, R_w = 0.077.

Crystals of *1* were grown by the slow diffusion of hexane into a CH_2Cl_2 solution of *1*. Data were collected on a Snytex P3 automated diffractometer (Mo Kα1, λ = 0.71069 Å) using a variable scan rate and a Θ-2Θ scan mode to a maximum 2Θ value of 60.0°. Data were corrected for Lorentz, polarization, absorption and background effects. Observed reflections (4302, I.3.0σ(I)) were used for the solution of the heavy atom positions by direct methods. Refinement of scale factor, positional and anisotropic thermal parameters for all atoms was carried out to convergence. Disorder of the BF_4 group became apparent and was accounted for with one fluorine atom in a full occupancy position and the six others in 50% occupancy positions. The 50% occupancy of the CH_2Cl_2 group was estimated from temperature parameters. Hydrogen atoms of the cyclopentadienyl ring and the CH and CH_2 groups of the isobutyl substituent were located from a difference Fourier synthesis. Phenyl hydrogen atoms were placed in positions calculated using idealized geometry and a C-H distance of 0.97Å. Hydrogens of the methyl groups and of the methylene chloride were not located. Final cycles of least squares refinement were completed with anisotropic thermal parameters for all atoms, leading to a final agreement factor, R=0.049, ($R = \Sigma| |F_o|-|F_c| |/\Sigma|F_o|$). In the final stages of refinement a weight of $1/\sigma(F)^2$ was used. R_w = 0.077.

Crystals of *2* were grown by the slow diffusion of pentane into a CH_2Cl_2 solution of 2. All measurements were made on an Enraf-Nonius CAD-4 diffractometer with graphite monochromated Mo Kα radiation. A linear correction factor was applied to the data to account for the decay. Data were collected using the ω-2Θ scan technique to a maximum 2Θ value of 40.0°. The data were corrected for Lorentz and polarization effects and an analytical absorption correction was applied.

The structure was solved by direct methods and

refined by full matrix least-squares. The final cycle of the full matrix least-squares refinement was based on 3294 observed reflections ($I > 3.00\ \sigma(I)$) and 467 parameters and converged with $R = 0.048$, $R_w = 0.061$. The hydrogen atoms were constrained to idealized positions (C-H = 0.95 Å) except for the H atom attached to the S, which is reported at a position indicated on a difference map, however the peak height of the position was comparable to the general noise level on the final difference map. The position is supported however by the reasonable bond angles it generates. The overall quality of the final refinement was negatively effected by three regions of disorder: the BF_4 anion, which was modeled by one F of occupancy factor 1.00, three at 0.75 and three at 0.25; the solvent molecule which exhibited large thermal motion; and the butyl group, the terminal C atoms also showing large thermal motion (this could explain the short C44-C45 distance of 1.13 Å). The atoms of these three regions were refined with isotropic thermal factors, while all other non-hydrogen atoms were refined anisotropically.

The dechlorination of CpRu $(PPh_3)_2Cl$ with $AgBF_4$ in the presence of the organic thiol leads to the formation of moisture sensitive, yellow products in moderate to good yields. In all cases, the IR spectrum shows a change in the S-H stretch from the free (unbound) mercaptan to the coordinated mercaptan (Table 1). The ν_{SH} stretch for the $Cr(CO)_5$(t-butylSH) compound has been assigned to a peak at 2555 cm^{-1} (Darensbourg et al., 1990). The change in the S-H stretching frequency appears to be a function of steric bulk; the smaller straight-chain R groups, n-propyl and $-CH_2CH_2SH$, show a smaller change in frequency than the larger t-butyl, phenethyl and benzyl R groups. Conroy-Lewis and Simpson (1991) have prepared two Ru-t-butyl mercaptan complexes, [CpRu(dppm) (t-C_4H_9SH)]PF_6 and [CpRu(PPh_3) (t-C_4H_9NC) (t-C_4H_9SH)]PF_6. The S-H stretch was too weak to be observed in the dppm complex. In [CpRu(PPh_3) (t-C_4H_9NC) (t-C_4H_9SH)]PF_6, the ν_{S-H} is 2544 cm^{-1}.

The structures of *1* and *2* show the Ru atom bound to the Cp, two P atoms of the PPh_3 ligands and the S of the isobutyl mercaptan (Fig. 1) or s-butyl mercaptan (Fig. 2). The Ru-S distances of 2.375(2) in *1* and 2.379(2) Å in *2* are similar to the Ru-S distance of 2.377 (2) Å in [CpRu$(PPh_3)_2$(n-C_3H_7SH)]BF_4 (Amarasekera and Rauchfuss, 1989) but considerably shorter than the Ru-S distance of 2.396(2) Å in [CpRu$(PPh_3)_2$(t-C_4H_9SH)]BF_4 (Minick et al., 1993). The structure of [CpRu(dppm) (t-C_4H_9SH)]PF_6 shows a Ru-S distance of 2.371 Å (Conroy-Lewis and Simpson, 1991). The S-H distance in *2* is 1.376 Å. This is considerably longer than the same distance in [CpRu$(PPh_3)_2$(n-C_3H_7SH)]BF_4 (Amarasekera and Rauchfuss, 1989) and [CpRu$(PPh_3)_2$(t-C_4H_9SH)]BF_4 (Minick et al., in press) (1.25 and 1.289(2) Å, respectivly). The S-H distance in $Cr(CO)_5$(t-butylSH) is 1.2(1) Å (Darensbourg et al., 1990).

Table 1. S-H Stretching Frequencies, ν, (cm^{-1}) and Force Constants, k, (mdynes/Å)[a] showing change upon coordination of thiols to $CpRu(PPh_3)_2^+$.

Mercaptan	Free	k	Bound	k
n-propyl	2560	3.773	2525	3.671
isopropyl	2558	3.767	2514	3.639
edt	2552	3.750	2519 (2568)	3.653 (3.797)
benzyl	2566	3.791	2512	3.633
phenethyl	2568	3.797	2515	3.642
n-butyl	2562	3.779	2517	3.648
isobutyl	2564	3.785	2515	3.642
s-butyl	2560	3.773	2512	3.633
t-butyl	2558	3.767	2504	3.610
$Cr(CO)_5$(t-BuSH)			2555[b]	3.759
[CpRu(PPh_3) (t-C_4H_9NC)-(t-BuSH)]PF_6			2544[c]	3.726
[CpRu(dppe) (phetSH)]BF_4			2517	3.648

a) $\Delta E = (h/2\pi)\ (k/\mu)^{1/2}$, $\mu = 1.6227 \times 10^{-27}$ kg
b) Darensbourg, et al., 1990
c) Conroy-Lewis and Simpson, 1991

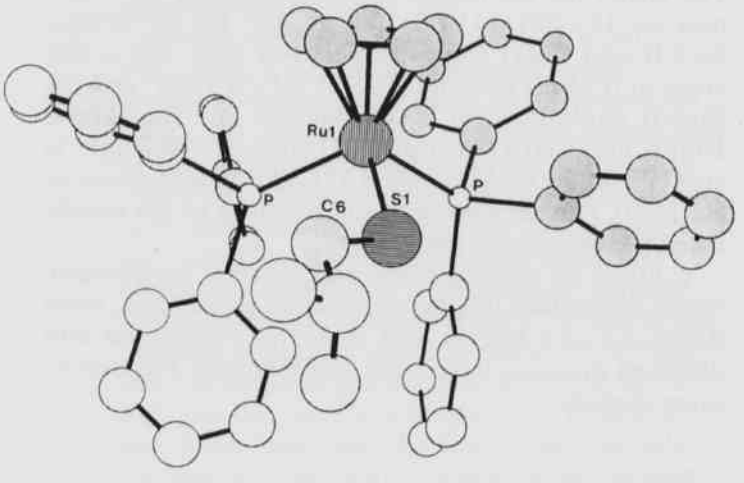

Fig. 1. Structure of the cation of [CpRu$(PPh_3)_2$(i-C_4H_9SH)]$BF_4 \cdot 1/2CH_2Cl_2$ showing coordination of i-C_4H_9SH. Selected bond distances (A) and angles (°): Ru1-S1 2.375(2), S1-C6 1.82(1), C6-S1-Ru1 113.6(3).

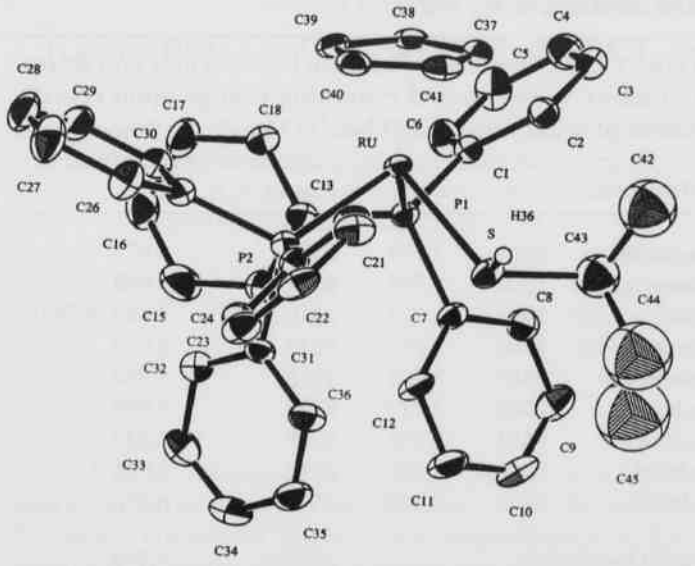

Fig. 2. Structure of $[CpRu(PPh_3)_2(s\text{-}C_4H_9SH)]BF_4 \cdot CH_2Cl_2$ showing cation atom labeling scheme. Selected bond distances (Å) and angles (°): Ru-S 2.379(2), S-C43 1.83(1), S-H36 1.376, C43-S-Ru 118.2(4), Ru-S-H36 106.37, C43-S-H36 98.24.

The angles about the S atom in *2* are 106.37° for Ru-S-H36, 98.24° for C43-S-H36 and 118.2(4)° for Ru-S-C43. The angles for the $[CpRu(PPh_3)_2(t\text{-}C_4H_9SH)]BF_4$ complex are 125.7(3), 111.7(1) and 91.9(3)° for the C-S-Ru, Ru-S-H and C-S-H angles respectively [17]. The C-S-H angle in $[CpRu(PPh_3)_2(n\text{-}C_3H_7SH)]BF_4$ is 99(3)° and the Ru-S-H angle is 97(3)° (Amarasekera and Rauchfuss, 1989). For $Cr(CO)_5$(t-butylSH), the Cr-S-H angle is 106(1)° and the Cr-S-C angle is 121.3(2)° (Darensbourg et al., 1990). Further studies of the reactivity of the coordinated mercaptans are under way.

A listing of atomic coordinates, general temperature factor expressions (U), hydrogen atom coordinates, bond distances and angles and tables of calculated and observed structure factors are available from the authors upon request.

Acknowledgements

Funding provided by the American Chemical Society Project SEED, the A.S.U. Faculty Research Committee and Competitive Applied Research Grant.

Literature Cited

Amarasekera, J. and **T.B. Rauchfuss.** 1989. Interconversion of persulfido, sulfur hydride, and hydride ligands coordinated to $CpRu(PPh_3)_2^+$ Inorg. Chem. 28:3875- 3883.

Conroy-Lewis, F.M. and **S.J. Simpson.** 1991. Molecular mercaptan (thiol) complexes: The sythesis of the tert-butanethiol complexes $[Ru(\eta^5\text{-}C_5H_5)(PPh_3)(Bu^tNC)(Bu^tSH)]PF_6$ and $[Ru(\eta^5\text{-}C_5H_5)(dppm)(Bu^tSH)]PF_6$ and the x-ray single crystal structure of $[Ru(\eta^5\text{-}C_5H_5)(dppm)(Bu^tSH)]PF_6$ [dppm = bis (diphenylphosphi no) methane]. J. Chem. Soc., Chem. Commun. 388-389.

Darensbourg, M.Y., E.M. Longridge, V. Payne, J. Reibenspies, C.G. Riordan, J.J. Springs and **J.C. Calabrese.** 1990. Isolation of chromium(0) thols: Molecular structure of $(Bu^tSH)Cr(CO)_5$. Inorg. Chem. 29:2721-2726.

Minick, D., J.W. Crump, M. Draganjac and **A.W. Cordes.** 1993 Crystal and molecular structure of $[CpRu(PPh_3)_2(t\text{-}C_4H_9SH)]BF_4$. J. Cryst. Spec. Res., 23:629-632.

Changes in the Nomenclature and Composition of the Arkansas Fish Fauna from 1988 to 1993

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A number of changes in the nomenclature and composition of the Arkansas ichthyofauna have occurred since the appearance of Robison and Buchanan's (1988) treatise on the fishes of Arkansas. We listed 215 species of fishes inhabiting state waters including 197 native species, two of which were undescribed, and 18 introductions. Although we were aware of many of the impending nomenclatural changes for Arkansas fishes, these anticipated changes were to be published subsequent to 1988 (e.g., Robins et al., 1991; Mayden, 1989) and we decided to use established ichthyological nomenclature rather than acting prematurely in anticipation of possible changes.

Leis and Paxton (1993) in a review of Robins et al. (1991) reminded nonsystematists that instability in nomenclature is understandably difficult for them, because they may not appreciate the dual purpose of binomial nomenclature: (1) to provide a "handle" for each species, and (2) to provide an hypothesis of relationships. Instability results as hypotheses change and as systematists interpret and implement the Code of Zoological Nomenclature.

Since the appearance of Robison and Buchanan (1988) three important works affecting Arkansas fishes have been published, namely Mayden (1989), Robins et al. (1991), and Coburn and Cavender (1992). Mayden (1989) elevated a number of subgenera within the former cyprinid genera, *Hybopsis* and *Notropis*. The result has been widespread nomenclatural changes which affect Arkansas fishes. Review of recent revisions hopefully will assist the nonsystematist working with Arkansas fishes who may be confused by, or unaware of, changes.

To keep workers on Arkansas fishes updated, recent changes in the Arkansas ichthyofauna are presented. Biologists employed by state and federal agencies, colleges and universities, or the private sector, need as complete a record as possible before attempting to evaluate the impact of environmental alterations, population status, management, protocol, speciation events, and biogeographic patterns or to direct students (Cashner and Matthews, 1988).

Changes were grouped into two categories: Species Additions and Nomenclatural Changes.

Species Additions

Cyprinidae - Carps and Minnows

1. *Luxilus cardinalis* (Mayden). Cardinal shiner. Formerly, *Notropis sp.* undescribed. Robison and Buchanan (1988) included the cardinal shiner as an undescribed *Notropis* (p. 225-226) in Arkansas. While the *Fishes of Arkansas* was in press, the formal description of the cardinal shiner appeared in which Mayden (1988) designated *Notropis pilsbryi* populations of the Arkansas River drainage of Arkansas, Oklahoma, Kansas, and Missouri, in addition to the Red River populations in Oklahoma, as a new species, *Notropis cardinalis*. An addendeum to Robison and Buchanan (1988:253) was added to note the change. Later, Mayden (1989) formally elevated the subgenus *Luxilus* of *Notropis* to generic level. *Luxilus pilsbryi* is thus confined to the White River system of Arkansas and Missouri.
2. *Scardinius erythrophthalmus* (Linnaeus). Rudd. The rudd is a wide ranging cyprinid native to Europe and central Asia (Berg, 1949; Banarescu, 1964). The earliest verified date of the introduction of the rudd to the United States was 1916 (Cahn, 1927). Courtney et al. (1986) provided a history of the rudd's introduction and early distribution in the United States. In the early 1980's the rudd underwent an explosive anthropogenic dispersal similar to that of the common carp (Burkhead and Williams, 1991). The recent dispersal of the rudd was due primarily to successful marketing by the Arkansas fish farming industry of the rudd as a new, hardy, and colorful bait minnow. The rudd has been distributed in 14 states and has escaped or been released and subsequently captured in eight states (Pigg and Pham, 1990). The rudd has become a popular bait fish used for striped bass fishing. Recently, Burkhead and Williams (1991) reported the disturbing news that the rudd could hybridize with the golden shiner (*Notemigonus crysoleucas*). Jennings et al. (1990) reported the rudd collected in the open waters of Lonoke

County, Arkansas. The Game and Fish Commission received one verbal report of a single specimen taken from the White River drainage following the December, 1987 flooding of over 4000 acres of minnow farms in Lonoke and Prairie counties. On 24 May 1991 Jeff Farwick collected two specimens of the rudd in Horseshoe Lake, Crittenden County (Ken Shirley, pers. comm.).

Nomenclatural Changes

Salmonidae - Trouts

1. *Oncorhynchus mykiss* (Walbaum). Rainbow trout. Two recent discoveries involving the rainbow trout have necessitated a scientific name change for this and other trout species (Smith and Stearly, 1989). First, the rainbow trout, *Salmo gairdneri* Richardson, has been shown to be the same as the earlier described Kamchatka trout, *Salmo mykiss* Walbaum. Second, studies of osteology (Vladykov, 1963; Cavender and Miller, 1982; and Sanford, 1987) and biochemistry (Berg and Ferris, 1984) of trouts and salmons indicate that rainbow trout and cutthroat trout and their relatives, the golden, Mexican, Gila, and Apache trouts, are related more closely to Pacific salmons (genus *Oncorhynchus*) than to brown trout and Atlantic salmon (*Salmo*) (See discussion by Smith and Stearly, 1989). Based on the arguments of these investigators, Robins et al. (1991) accepted *Oncorhynchus* for the Pacific salmonids leaving *Salmo* as the genus of salmonids native to Europe, western Asia, and the Atlantic basin. Thus the rainbow trout becomes *Oncorhynchus mykiss* (Walbaum).
2. *Oncorhynchus clarki* (Rafinesque). Cutthroat trout. Smith and Stearly (1989) showed that relationships of the trouts of the cutthroat and rainbow series lie with the genus *Oncorhynchus* rather than *Salmo*. The cutthroat trout, formerly known as *Salmo clarki*, is now *O. clarki*.

Cyprinidae - Carps and minnows.

3. *Cyprinella camura* (Jordan and Meek). Bluntface shiner. The bluntface shiner, formerly *Notropis camurus*, is a member of the subgenus *Cyprinella* elevated by Mayden (1989) to full generic status.
4. *Cyprinella galactura* (Cope). Whitetail shiner. Formerly *Notropis galacturus*.
5. *Cyprinella lutrensis* (Baird and Girard). Red shiner. Formerly was *Notropis lutrensis*.
6. *Cyprinella spiloptera* (Cope). Spotfin shiner. Formerly *Notropis spilopterus*.
7. *Cyprinella venusta* Girard. Blacktail shiner. Formerly *Notropis venustus*.
8. *Cyprinella whipplei* Girard. Steelcolor shiner. Formerly *Notropis whipplei*.
9. *Erimystax harryi* (Hubbs and Crowe). Ozark chub. The Ozark chub was formerly considered a sub species of *Hybopsis dissimilis*, the streamline chub. The streamline chub is now placed in the genus *Erimystax* (gender masculine) on the basis of recent genealogical analysis by Coburn and Cavender (1992) and Mayden (1989). Harris' (1986) dissertation provided the documentation for elevation of *Hybopsis dissimilis harryi* to species level. Because of the aforementioned studies this chub is now known as *Erimystax harryi*, the Ozark chub.
10. *Erimystax x-punctatus* (Hubbs and Crowe). Gravel chub. Formerly known as *Hybopsis x-punctata*. See above discussion on the genus *Erimystax*.
11. *Luxilus chrysocephalus* Rafinesque. Striped shiner. Although Robison and Buchanan (1988) used the name *Notropis chrysocephalus* for the striped shiner in Arkansas, this form has been the source of continuous debate for years. Mayden (1989) elevated the subgenus *Luxilus* of *Notropis* to generic status, an action supported by Coburn and Cavendar (1992) and used in Robins et al. (1991), thus we recognize *Luxilus chrysocephalus* as the correct name of the striped shiner.
12. *Luxilus pilsbryi* (Fowler). Duskystripe shiner. Formerly *Notropis pilsbryi*.
13. *Luxilus zonatus* (Putnam). Bleeding shiner. Formerly *Notropis zonatus*.
14. *Lythrurus fumeus* (Evermann). Ribbon shiner. Formerly *Notropis fumeus*. This generic change is due to Mayden's (1989) elevation of the *Lythrurus* group to generic level.
15. *Lythrurus snelsoni* (Robison). Ouachita Mountain shiner. Formerly *Notropis snelsoni*. Although Robins et al. (1991) used the common name Ouachita shiner, we retain the common name Ouachita Mountain shiner as used by Robison (1985) as a more descriptive name for this Ouachita Mountain endemic species. Changing to simply "Ouachita shiner" seems to imply that this fish lives in the Ouachita River system which it does not.
16. *Lythrurus umbratilis* (Girard). Redfin shiner. Formerly *Notropis umbratilis*.
17. *Macrhybopsis aestivalis* (Girard). Speckled chub. The speckled chub was formerly called *Hybopsis aestivalis*. Coburn and Cavendar (1992) rearranged the species of the polyphyletic "genus" *Hybopsis* and resurrected the genus *Macrhybopsis* for the four species of barbelled minnows (*aestivalis, geli-*

da, *meeki* and *storeriana*), all of which occur in Arkansas waters. Mayden (1989) placed the speckled chub in the monotypic genus *Extrarius*; however, we follow Coburn and Cavendar (1992) as did Robins et al., (1991).

18. *Macrhybopsis gelida* (Girard). Sturgeon chub. Formerly *Hybopsis gelida*.
19. *Macrhybopsis meeki* (Jordan and Evermann). Sicklefin chub. Formerly *Hybopsis meeki*.
20. *Macrhybopsis storeriana* (Kirtland). Silver chub. Formerly *Hybopsis storeriana*.
21. *Notropis amblops* (Rafinesque). Bigeye shiner. The bigeye shiner was formerly known as *Hybopsis amblops*. In his dissertation Clemmer (1971) regarded *Hybopsis amblops*, *Notropis amnis*, and four other species as an intimately interrelated group. Later, Mayden (1989) accepted these six forms as a monophyletic group and more recently, Coburn and Cavendar (1992) classified the six as a subgenus of *Notropis*, an action which Robins et al. (1991) accepted. Since *Notropis* (*Hybopsis*) *amblops*, as *Hybopsis gracilis* Agassiz, 1854 is the type species of *Hybopsis*, this move restricts the name to these six species as a subgenus, thus the "genus" *Hybopsis* is no longer recognized (Robins et al. (1991).
22. *Opsopoeodus emiliae* Hay. Pugnose minnow. Formerly *Notropis emiliae*. Gilbert and Bailey (1972) transferred this fish to the genus *Notropis*; however, recent discoveries in breeding behavior (Page and Johnson, 1990) and osteology (Coburn and Cavender, 1992) point to a sister-group relationship with *Pimephales*. We are following these investigators in retaining the genue *Opsopoeodus* for the pugnose minnow.
23. *Platygobio gracilis* (Richardson). Flathead chub. Formerly *Hybopsis gracilis*. Ictaluridae - Bullhead catfishes.
24. *Ameiurus catus* (Linnaeus). White catfish. Formerly *Ictalurus catus*. Bailey and Robins (1988) noted that, under the 1985 Code of Zoological Nomenclature, names proposed for divisions of genera are valid and available. This action made *Ameiurus*, held to be invalid under previous codes, a valid and available name. Lundberg (1982) had earlier separated *Ameiurus* from *Ictalurus* and we recognize this action as did Robins et al. (1991).
25. *Ameiurus melas* (Rafinesque). Black bullhead. Formerly *Ictalurus melas*.
26. *Ameiurus natalis* (Lesueur). Yellow bullhead. Formerly *Ictalurus natalis*.
27. *Ameiurus nebulosus* (Lesueur). Brown bullhead. Formerly *Ictalurus nebulosus*.

Centrarchidae - Sunfishes

28. *Lepomis miniatus* Jordan. Redspotted sunfish. Formerly *Lepomis punctatus*. Warren (1992) elevated the western subspecies of the spotted sunfish, *L. p. miniatus*, to specific status and we concur.
29. *Micropterus dolomieu* Lacepede. Smallmouth bass. Formerly *Micropterus dolomieui*. A popular game species, the smallmouth bass has had its name changed slightly. Originally, the smallmouth bass was named for M. Dolomieu, a French mineralogist for whom the mineral dolomite also was named. Bailey and Robins (1988) noted that patronymic names proposed in apposition with the generic name are approved by the 1985 Code (Article 31a) and that, therefore, the "i" previously added to such names is to be dropped and the original name retained.

Percidae - Perches

30. *Crystallaria asprella* (Jordan). Crystal darter. Formerly *Ammocrypta asprella*. Simons (1991) resurrected the monotypic genus *Crystallaria* for the crystal darter which forms the sister group to all other darters.
31. *Percina vigil* (Hay). Saddleback darter. Formerly *Percina ouachitae*. Because of extensive analysis of Suttkus (1985), this species was changed by Robins et al. (1991) to *Percina vigil*, an action which we accept.

These 31 nomenclatural changes and the formal description of one previously undescribed species, plus the addition of one introduced species, the rudd, to the state ichthyofaunal list bring the current total number of fishes in the state of Arkansas to 216. Of this number, 197 species are native while 19 were introduced deliberately or inadvertently by man.

Literature Cited

Bailey, R.M. and **C.R. Robins.** 1988. Changes in North American fish names, especially as related to the international code of nomenclature, 1985. Bull. Zool. Nomencl. 45(2): 92-103.

Banarescu, P. 1964. Fauna republicii populare Romine. Pices-Osteichthyes, volume 8. Editurea Academiei Republicii Populare Romine, Bucuresti.

Berg, L.S. 1949. The freshwater fishes of the U.S.S.R. and adjacent countries, Vol. 2. 4th ed. Isreal Program for Scientific Translation (1964). Jerusalem.

Berg, W.J. and **S.D. Ferris.** 1984. Restriction endonuclease analysis of salmonid mitochondrial DNA. Can. J.

Fish. Aquat. Sci. 45: 122-131.

Burkhead, N.M. and **J.D. Williams.** 1991. An intergeneric hybrid of a native minnow, the golden shiner, and an exotic minnow, the rudd. Trans. Amer. Fish. Soc. 120: 781-795.

Cashner, R.C. and **W.J. Matthews.** 1988. Changes in the known Oklahoma fish fauna from 1973 to 1988. Proc. Okla. Acad. Sci. 68: 1-7.

Cahn, A.R. 1927. The European rudd (*Scardinius*) in Wisconsin. Copeia 162: 5.

Cavender, T.M. and **R.R. Miller.** 1982. *Salmo australis*, a new species of fossil salmonid from southwestern Mexico. Contrib. Mus. Paleontol. Univ. Mich. 26: 1-17.

Clemmer, G.H. 1971. The systematics and biology of the *Hybopsis amblops* complex. Ph.D. Diss. Tulane Univ. New Orleans. 155 pp.

Coburn, M.M. and **T.M. Cavender.** 1992. Interrelationships of North American cyprinid fishes, Pp. 328-373, *In* Systematics, historical ecology, and North American Freshwater fishes. (ed. R. L. Mayden). Stanford Univ. Press. Stanford.

Courtney, W.R., Jr., D.A. Hensley, J.N. Taylor and **J.A. McCann.** 1986. Distribution of exotic fishes in North America. Pp. 675-698, *In* The zoogeography of North American freshwater fishes. (C. H. Hocutt and E. O. Wiley, eds). Wiley. New York.

Gilbert, C.R. and **R.M. Bailey.** 1972. Systematics and zoogeography of the American cyprinid fish *Notropis* (*Opsopoeodus*) *emiliae*. Occas. Papers Mus. Zool., Univ. Mich. No. 664: 35 p.

Harris, J.L. 1986. Systematics, distribution and biology of fishes of allocated to *Erimystax* (Jordan), a subgenus of *Hybopsis* (Cyprinidae). University of Tennessee. Knoxville. 334 pp.

Leis, J.M. and **J.R. Paxton.** 1993. Review: Common and scientific names of fishes of the United States and Canada. Copeia 3(1): 245-248.

Lundberg, J.G. 1982. The comparative anatomy of the toothless blindcat, *Trogloglanis pattersoni* Eigenmann, with a phylogenetic analysis of the ictalurid catfishes. Misc. Publ. Mus. Zool. Univ, Michigan 163:1-85.

Jennings, D.P., J.D. Williams, and **N.M. Burkhead.** 1990. Current status of rudd, *Scardinius erythrophthalmus*, in the United States. Am. Soc. Ichthyol. Herpetol., Annual Meeting Abstracts. p. 103.

Mayden, R.L. 1988. Systematics of the *Notropis zonatus* species group, with description of a new species from the Interior Highlands of North America. Copeia 1988 (1): 153-173.

Mayden, R.L. 1989. Phylogenetic studies of the North American minnows, with emphasis on the genus *Cyprinella* (Teleostei: Cypriniformes). Misc. Publ. Mus. Nat. Hist. Univ. Kansas 80: 1-189.

Page, L.M. and **C.E. Johnson.** 1990. The breeding behavior of *Opsopoeodus emiliae* (Cyprinidae) and its phylogenetic implications. Copeia 1990: 1176-1180.

Pigg, J. and **T. Pham.** 1990. The rudd, *Scardinius erythrophthalmus*, a new fish in Oklahoma waters. Proc. Okla. Acad. Sci. 70: 37.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and **W. B. Scott.** 1991. Common and scientific names of fishes from the United States and Canada. Fifth ed. American Fisheries Society Spec. Publ. 20. 183 p.

Robison, H.W. 1985. *Notropis snelsoni*, a new cyprinid from the Ouachita Mountains of Arkansas and Oklahoma. Copeia 1985 (1): 126-134.

Robison, H.W. and **T.M. Buchanan.** 1988. Fishes of Arkansas. Univ. Arkansas Press. Fayetteville. 536 pp.

Sanford, C.P.S. 1987. Salmonid inter- and intrarelationships. p. 78, *In* American Society of Ichthyologists and Herpetologists, Program and Abstracts.

Simons, A.M. 1991. The phylogenetic relationships of the crystal darter, *Crystallaria asprella*. Copeia 1991:927-936.

Smith, G.R. and **R.F. Stearley.** 1989. The classification and scientific names of rainbow and cutthroat trouts. Fisheries 14 (1): 4-10.

Suttkus, R.D. 1985. Identification of the percid *Ioa vigil* Hay. Copeia 1985: 225-227.

Vladykov, V. 1963. A review of salmonid genera and their broad geographical distribution. Trans. R. Soc. Can. Series 4, Vol. 1, Section 3: 459-504.

Warren, M.L., Jr. 1992. Variation of the spotted sunfish, *Lepomis punctatus* complex (Centrarchidae): meristics, morphometrics, pigmentation and species limits. Bull. Ala. Mus. Nat. Hist. No. 12: 47 p.

Occurrence of Hybrid Honey Locust (*Gleditsia* x *texana* Sarg.) in Southwest Arkansas

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The genus *Gleditsia* (Fabaceae) is represented in the United States by two distinctive species and a putative hybrid between them. The most widespread is honey locust, *G. triacanthos* L., with a natural range centered on the Mississippi drainage basin (Little, 1971) and common throughout Arkansas. It is characterized by long pods with a sweet pulp–the "honey"– between the many seeds. Water locust, *G. aquatica* Marsh., occurs in swamps and wet bottomlands on the Atlantic and Gulf Coastal Plains and in the Mississippi and Ohio River valleys. Smith (1988) indicated the distribution in Arkansas to be in the Mississippi Delta and West Gulf Coastal Plain divisions. It is characterized by short pulpless pods, each with one or occasionally up to three seeds. The putative hybrid of honey locust and water locust has been designated *G.* x *texana* Sargent. It is known in relatively few, widely scattered sites where both putative parent species also occur. It is morphologically intermediate between the other two taxa, with the range in fruit length being the most striking characteristic. Sympatric occurrences of honey locust and water locust are fairly common in southern Arkansas, but the occurrence of the putative hybrid in Arkansas has been previously documented only for Lee County (Gordon, 1966; Smith, 1988). Here we report the occurence of *G.* x *texana* in Clark County. We are grateful to Eric Davis for his help with field collections.

After compiling an initial catalog of the woodland trees of Clark County, Arkansas, which listed both *Gleditsia triacanthos* and *G. aquatica* (Marsh 1986), DLM began searching for the hybrid in sites where both the species were found. Honey locust was common throughout the county, and water locust was found scattered in the Ouachita and Little Missouri River bottomlands.

On October 21, 1992, during a dendrology class field trip, a putative hybrid *Gleditsia* was found on the Ouachita River floodplain. The site was just north of Arkadelphia at the south boundary of the Caddo River Ranch (Clark Timberlands) in Section 5, Township 7 South, Range 19 West. The variable pods found on the ground by Smith, Marsh, and Davis indicated that the tree was *Gleditsia* x *texana*. Leaves and attached pods high in the tree could not be reached for collection on the day of discovery. Smith and Davis returned to the site on October 23 to collect leafy twigs with pods by shooting through the twigs with a rifle. Voucher specimens (Smith 75) were prepared for the Herbarium of Henderson State University. The tree was thornless, with a DBH of 21.5 cm. The height was estimated as about 12 m. The pods were variable in length (3.5-21.5 cm), shape (falcate or straight), and amount of pulp. All variations of fruit illustrated by Vines (1960) were present, and all characters which could be examined matched published descriptions of *Gleditsia* x *texana*. The tree was located in second growth, bottomland hardwoods. The area was rather poorly drained and occasionally flooded. Honey locust was common in the area, and a slough just to the east of the site provided the habitat suitable for water locust.

Additional field investigation yielded two more *G.* x *texana* individuals and two trees of problematical status. One of the hybrid honey locusts was near the first tree we had found; the other about a half mile to the north. Both were similar to the first in size and nearly thornless. The last was growing beside a very thorny honey locust, about the same size. The area between the first two trees and the third is swampy and seems likely to yield additional specimens with further search during the next growing season.

The two problematical trees were found a short distance north of the original site on the eastern edge of the Caddo River Ranch. The first was a honey locust with unusually narrow pods. Many pods were still on the tree, but only two could be collected. They were about 30 cm long and somewhat falcate, but without the corkscrew twist characteristic of dried honey locust fruits. The pods were flat and devoid of pulp. The other aberrant tree had a broad crown retaining many dried fruits, more than any other tree we observed in early March. Pods on different limbs were of different lengths, from less than 15 cm up to 35 cm. Some pods were curved and appeared to have pulp. The tree appeared to be thornless throughout.

Several trees found on the sloughs were tentatively identified as water locusts, but no pods were present for confirmation.(The presence of water locusts was confirmed the following growing season.) Common honey locust occurred throughout the area, especially on better drained sites, many still retaining typical pods.

Vines (1977) described what seemed to be an extensive hybrid population of "Texas locust" at the type locality in the Brazos River bottomlands near Brazoria, Texas. His description of intergrading variability certainly seems to correspond to the patterns found in hybrid plant populations which were described by Anderson (1949), and raises the question of the role of introgressive hybridization in the evolution of the Texas population. Anderson

(1949, p. 62-63) discussed the probable importance of introgression in producing the genetic variability characteristic of river-valley plants. A hybrid population such as that which may occur on the Brazos River provides a natural laboratory for the study of the role of introgression in biological evolution. Our preliminary findings suggest the possibility of such a population on the Ouachita River in Arkansas. Discovery of the two aberrant trees also raises interesting questions. Do these represent only minor variations of *Gleditsia triacanthos*, or might they be products of introgression between *G. triacanthos* and *G. aquatica* closer to *G.* x *texana*? We look forward with great interest to further investigations of the honey locust relatives of the Ouachita River floodplain.

As we reviewed the literature we found that Demaree (1943) had listed *Gleditsia texana* (without the hybrid designation) in his catalog of the vascular plants of Arkansas, citing Branner and Coville (1891) as the source. We noted with interest that this source antedated the original description of *G. texana* by Sargent (1901). Evidently Demaree recognized that the item which Branner and Coville (1891) listed as "*Gleditschia tracanthos* var. *brachycarpus*, Michx.; Nuttall" corresponded to Sargent's *G. texana*. A detailed study of the literature indicated that the hybrid honey locust was first found in Arkansas in 1819 by Nuttall (1821), some 80 years before Sargent found it in Texas. A full review of the relative literature will appear in the next *Academic Forum* published at Henderson State University.

Sargent (1922) listed only Texas, Louisiana, Mississippi, and Indiana as locations for *G.* x *texana*, and Vines (1960, 1977) gave only the same four states for the range. So far as we can find the first source after Demaree (1943) to include Arkansas in the range of *G.* x *texana* was the revision by Gordon (1966). Isely (1975) added north Florida and South Carolina to the range, designating it as "sporadic and rare". Vines (1960, 1977) and Robertson and Lee (1976) are among the mo lern authors who state that the hybrid honey locust was first discovered in Texas, ignoring the earlier listings in Arkansas. Although Vines adopted "Texas honey-locust" as the English name for the hybrid species, we prefer hybrid honey locust as the designation. Most modern authors consider the entity to be a hybrid species and place the "X" symbol in the binomial (Vines, 1960, 1977; Gordon, 1966; Isely, 1975; Robertson and Lee, 1976).

Literature Cited

Anderson, E. 1949. Introgressive hybridization. John Wiley & Sons, New York.

Branner, J. C. and **F. V. Coville.** 1981. A list of the plants of Arkansas. Annural Report for 1988. Ark. Geolog. Survey 4:155-242.

Demaree, D. 1943. A catalogue of the vascular plants of Arkansas. Taxodium 1:1-88.

Gordon, D. A. 1966. A revision of the genus Gleditsia (Leguminosae). Ph.D. thesis, Indiana University. University Microfilms 66-14,824. 115 pp.

Isely, D. 1975. Leguminosae of the United States: II. Subfamily Caesalpinioideae. Mem. New York Bot. Gard. 25(2): 1-228.

Little, E.L. 1971. Atlas of United States trees. Vol. 1. U. S. Dept. Agri. Misc. Pub. No. 1146.

Marsh, D.L. 1986. The woodland trees of Clark County, Arkansas. Academic Forum 4:64-73.

Nuttall, T. 1821. A journal of travels into the Arkansas Territory, during the year 1819. T. H. Palmar, Philadelphia.

Robertson, K.R. and **Y.T. Lee.** 1976. The genera of Caesalpinioideae (Leguminosae) in the southeastern United States. J. Arnold Arboretum 57(1): 1-53.

Sargent, C.S. 1901. New or little known North American trees. II. Bot. Gaz. 31(1): 1-16.

Sargent, C.S. 1922. Manual of the trees of North America, 2nd ed. Dover Publications reprint. New York. Vol. 2, pp. 607-611.

Smith, E.B. 1988. An atlas and annotated list of the vascular plants of Arkansas, 2nd ed. Published by the author.

Vines, R.A. 1960. Trees, shrubs and woody vines of the Southwest. University of Texas Press, Austin.

Vines, R.A. 1977. Trees of East Texas. University of Texas Press, Austin.

Caudal Hedonic Glands in the Dark-sided Salamander, *Eurycea longicauda melanopleura* (Urodela: Plethodontidae)

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Male salamanders within the genus *Eurycea* possess clusters of acinar, exocrine glands (called caudal hedonic glands) embedded in the skin on the middorsal and lateral regions of the tail directly above the vent; they extend posteriorly for several mm as part of an elevated ridge which is quite conspicuous during the breeding season (Noble, 1929; Sever, 1985, 1989). Furthermore, these glands are lacking in females. Sever (1989) provided a historical as well as functional perspective on the nature of caudal hedonic glands. In brief, the glands, first detailed histologically in *Eurycea bislineata* by Noble (1929) and further elucidated in other species of *Eurycea* by Sever (op. cit.), produce secretions during the breeding season that are thought to function as a sexual attractant and play a major role in eliciting the stereotypic "tail-straddling" walk (Arnold, 1977) by females prior to spermatophore deposition by males during courtship behavior in *Eurycea* and possibly in other plethodontid salamanders. (Females place their snouts on the male's rump, and nasolabial grooves transfer chemicals to the nasal cavity.)

Histochemical studies dealing with the secretions of these glands as well as other hedonic glands in *Eurycea* species [e.g., mental hedonic glands (Sever, 1975a, 1976), nasolabial glands, (Sever, 1975b), and cloacal glands (Sever, 1980)] indicate that mucoproteins are released by both caudal hedonic glands and mental hedonic glands (Sever, 1989). A number histological studies yielding information on male reproductive anatomy (Ireland, 1974; Williams et al., 1976; 1984) or female spermathecal (Ireland, 1974) and cloacal anatomy (Sever, 1980) in *Eurycea longicauda* have been conducted; however, no studies have centered on the structure of caudal hedonic glands in this species. The objectives of the present study were to: 1) document the structure of caudal hedonic glands in the dark-sided salamander, *Eurycea longicauda melanopleura*, using light microscopy and 2) compare the morphology and secretions of these glands with similar glands previously reported in other *Eurycea*.

Sixteen male and 12 female adult specimens [males, 42-52 mm in snout-vent length (SVL), $\bar{x}$ = 47.7; females, 50-56 mm SVL, $\bar{x}$ = 52.7] of *E. l. melanopleura* were examined histologically during this study. Individuals were collected from caves or springheads in three northeastern Arkansas counties (Fulton, Independence, and Randolph); nearly all were taken from 15 September to 12 November, 1989, during their peak in reproductive activity (Ireland, 1974; Williams et al., 1984). [In fact, eleven of the 12 females examined were gravid (possessing enlarged vitellogenic ova); of these, eight exhibited spermatozoa within spermathecal tubules.] Salamanders were sacrificed in a dilute chloretone solution, fixed in 10% formalin for at least 48 h, and then stored in 70% ethanol. Tissues samples prepared for light microscopy were removed from the middorsal region of the tail in males and in females (for comparative purposes); in addition, the spermatheca (sperm storage gland of the dorsal cloacal wall) of females and the mental hedonic gland (on the chin) of males were also excised to provide information concerning timing of mating and degree of reproductive readiness (see Sever, 1976), respectively. Histological techniques followed those outlined by Humason (1979). Briefly, the procedures included dehydrating tissues in a graded series of ethanol, clearing in xylene, and embedding in paraffin. Paraffin blocks contained tissue previously oriented so that either sagittal, transverse, or frontal sections were obtained in complete serial sequences (at 8 µm in thickness). Three stains [hematoxylin and eosin = H & E (for general cytology); Pollak trichrome = Pollak (for connective tissues and mucosubstances); alcian blue (for sulfated mucosubstances)] were alternately used on sequential groups of three slides. All glands were measured using a calibrated ocular micrometer and are reported in µm as means (± 2 SE), followed by ranges in parentheses, and then by the number of glands examined. In caudal hedonic glands, only those exhibiting a bulbous, secretory portion were measured. Prepared slides and voucher specimens are deposited in the Arkansas State University Museum of Zoology (ASUMZ).

Caudal hedonic glands (found only in males) are multicellular acinar glands that show a high degree morphological variability (Fig. 1) ranging from being circular to oblong in the pre-secretory stage (Fig. 1C and D) to mostly flask-like during the secretory stage (Fig. 1E and F). No correlation was found between SVL and the size of these glands ($P > .05$). In addition, the columnar epithelium of caudal hedonic glands is variable in thickness in relation to secretory activity ($\bar{x}$ = 53.7 ± 6.9; 26.9 - 88.4; n = 20). These glands can be distinguished from other skin glands

(namely, mucous and grandular glands) by their size, configuration, and staining properties of their secretions. For example, caudal hedonic glands are much greater in length ($\bar{x}$ = 259.2 ± 6.6; 190.0 – 330.0; n = 67) and width ($\bar{x}$ = 192.5 ± 8.8; 115.0 – 300.0; n = 67) than either granular glands (length: $\bar{x}$ = 194.9 ± 16.9, 150.0 – 288.4, n = 16; width: $\bar{x}$ = 162.2 ± 6.9, 138.5 – 192.3, n = 16) or mucous glands (length: $\bar{x}$ = 74.4 ± 7.9, 61.5 – 92.3, n = 7; width: $\bar{x}$ = 83.6 ± 10.6, 69.2 – 107.7, n = 7). In addition, granular and mucous glands are mostly circular in structure (Fig. 1B), except (as in the case with granular glands) when both are oblong by being squeezed among the large caudal hedonic glands (Fig. 1D and F). The ratio of each gland by number in a 1.5 mm x 0.5 mm rectangle of tissue (viewed by frontal section) in the dorsal tail region is, however, in favor of granular glands in one male (8 mucous glands – 11%, 14 caudal hedonic glands - 19%, and 52 granular glands – 70%). The greatest concentration of caudal hedonic glands occurs within the anterior glandular fields of the elevated ridge, a region lying dorsal to the 4 to 6 dorsal myotomal muscle bundles which lie posterior to the sacrum (approximately 6 – 8 mm in total length). The number of glands decreased dramatically in regions not subtended by adipose tissue.

The staining properties of the glandular secretions are similar to those previously reported by Sever (1989) for

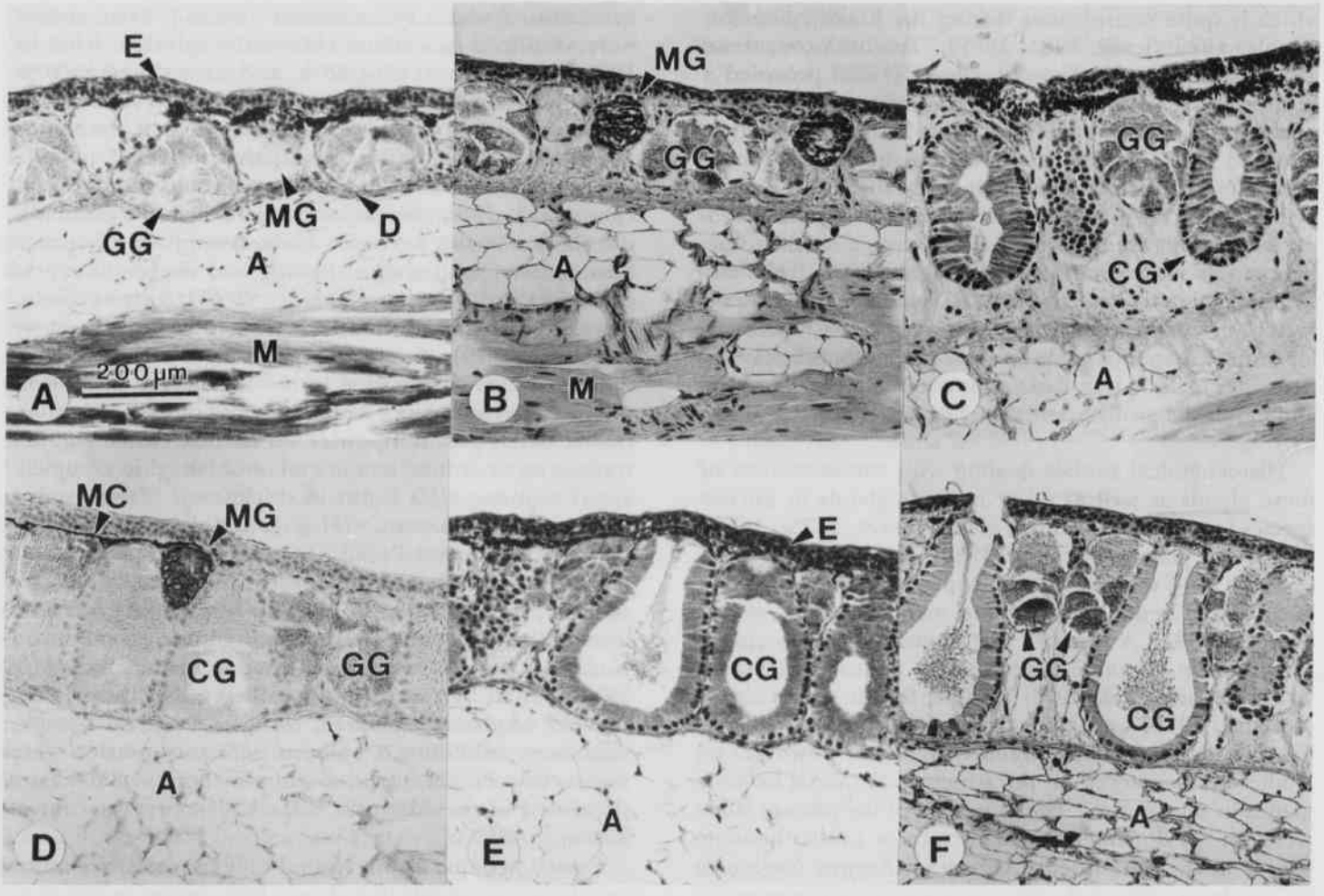

Fig. 1. Sagittal sections through the middorsal region of the tail directly above and posterior to the vent in *Eurycea longicauda melanopleura* illustrating the caudal hedonic glands and their relationship to other skin glands. Line in A (= 200 µm) is the same for B - F. A. Secion of female skin (ASUMZ 13938) stained with Pollak trichrome showing muccous glands (MG), granular glands (GG), a thin epidermis (E), the lower layer of the dermis (D) lying above adipose tissue (A), and the dorsal musculature (M). Notice that cells and secretions of the mucous glands fail to stain; granular glands are slightly acidophilic. B. Skin of male (ASUMZ 14258) stained with H & E illustrating an epidermal region (caudal portion of tail) devoid of caudal hedonic glands. The mucous glands exhibit a basophilic coloration; abbreviations are the same as those in A. C. Skin of male (ASUMZ 14250) stained with H & E showing the presence of early-developing, caudal hedonic glands (CG). D. Male (ASUMZ 13931) stained with alcian blue; both the caudal hedonic glands and the granular glands show no staining reaction compared to the brilliant blue of mucous glands. MC = layer of melanocyte cells. E and F. Caudal hedonic glands of male in D in region of maximum development (Pollak stain). The epithelial lining of the caudal hedonic gland appears light purple; the secretory column is also light purple, except for the portion near the pore of the gland which stains light-to-dark brown.

other *Eurycea*. In the following, we briefly summarize the reactions observed in the present study. Mucous glands liberate fibrous secretions that are weakly basiophilic using H & E and Pollak but are strongly positive (dark blue) with alcian blue, whereas glandular gland secretions are generally eosinophilic using H & E and Pollak (actually brown in color) but show no reaction to alcian blue. As mentioned above, Sever (1989) identified secretions from caudal hedonic glands as being comprised of mucoproteins. In *E. l. melanopleura*, these secretions were eosinophilic using H & E and showed no affinity for alcian blue; however, with Pollak, the reactions were mixed. In many cases, more than one coloration was evident within the secretory substance. For instance, in the narrowed, dorsal tubular neck of an individual gland (Fig. 1E and F), a secretory column possessing a cap (a secretory plug?) attached to a stalk stained light-to-moderately dark brown. The bulk of loosely-organized secretory material making up a central luminal mass and appearing light blue or purple gradually merged with or into this stalk. The above description was typical of a majority of the most well-developed caudal hedonic glands. Interestingly, nearly the same staining characteristic was evident in mental hedonic glands examined during this study (not pictured). The fact that both secretions are mucoproteins may partially explain the similarity in the nature of the secretory product.

The caudal hedonic glands of *E. l. melanopleura* differ in several respects from those of other species of *Eurycea* (*E. bislineata; E. cirrigera; E. junaluska; E. nana; E. wilderae*) as illustrated by Sever (1985, 1989). For one, the flask-like structure of these glands in the hypertrophied stage (as in *E. l. melanopleura*) was not demonstrated for these other species. Furthermore, the size of caudal hedonic glands in *E. l. melanopleura* is over twice as large as other species. The disparity in gland size can be attributed to differences in adult body size (*E. l. melanopleura* averaging around 10 mm greater in SVL compared of the other species). A study comparing the caudal hedonic glands of *E. lucifuga*, a species of comparable body size to *E. l. melanopleura*, is warranted and would help clarify species-specific differences within the genus.

Literature Cited

Arnold, S.J. 1977. The evolution of courtship behavior in New World salamanders with some comments on Old World salamanders. Pp. 141-183, *In* The reproductive biology of amphibians (D.H. Taylor and S.I. Guttman, eds.) Plenum Press, New York. x + 475 pp.

Humason, G.L. 1979. Animal tissue techniques, 4th ed. W.H. Freeman, San Francisco, ix + 661 pp.

Ireland, P.H. 1974. Reproduction and larval development of the dard-sided salamander, *Eurycea longicauda melanopleura* (Green). Herpetologica 30:338-343.

Ireland, P.H. 1979. *Eurycea longicauda.* Cat. Amer. Amph. Rept. 221.1-221.4.

Noble, G.K. 1929. The relation of courtship to the secondary sexual characters of the two-lined salamander, *Eurycea bislineata* (Green). Am. Mus. Novitates 362:1-5.

Sever, D.M. 1975a. Morphology and seasonal variation of the mental hedonic glands of the dwarf salamander, *Eurycea quadridigitata* (Holbrook). Herpetologica 31:241-251.

Sever, D.M. 1975b. Morphology and seasonal variation of the nasolabial glands of *Eurycea quadridigitata* (Holbrook). J. Herpetol. 9:337-348.

Sever, D.M. 1976. Morphology of the mental hedonic gland clusters of plethodontid salamanders (Amphibia, Urodela, Plethodontidae). J. Herpetol. 10:227-239.

Sever, D.M. 1980. Cloacal anatomy of male brook salamanders (*Eurycea*). Herpetologica 36:51-60.

Sever, D.M. 1985. Sexually dimorphic glands of *Eurycea nana, Eurycea neotenes* and *Typhlomolge rathbuni* (Amphibia: Plethodontidae). Herpetologica 41:71-84.

Sever, D.M. 1989. Caudal hedonic glands in salamanders of the *Eurycea bislineata* complex (Amphibia: Plethodontidae). Herpetologica 45:322-329.

Williams, A.A., R.A. Brandon and **J. Martan.** 1984. Male genital ducts in the salamanders *Eurycea lucifuga* and *Eurycea longicauda.* Herpetologica 40:322-330.

Williams, A.A., J. Martan and **R.A. Brandon.** 1976. Sperm associations in the male reporductive tract of *Eurycea longicauda* (Amphibia: Caudata). J. Reprod. Fert. 48:409-411.

Distribution of the Mole Salamander, *Ambystoma talpoideum* (Urodela: Ambystomatidae), in Arkansas with Notes on Paedomorphic Populations

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The mole salamander, *Ambystoma talpoideum*, is a small-bodied and relatively large-headed ambystomatid species distributed throughout much of the southeastern United States and is one of six species of *Ambystoma* that occurs in Arkansas (Conant and Collins, 1991). Our knowledge of the distribution of *A. talpoideum* has increased substantially during the past few decades, and gaps in its range have been filled in other states as well as in Arkansas (see distribution maps in Conant, 1958, 1975; Conant and Collins, 1991). Following its initial discovery from Clay County in northeastern Arkansas (Parker, 1947), five additional county records have been established during the last 15 years (Robison and Winters, 1978; Sutton and Paige, 1980; Meshaka and McLarty, 1988; Meshaka et al., 1989; Plummer and Dye, 1992). This species exhibits a disjunct distribution in Arkansas according to these records and as illustrated by Conant and Collins (1991); furthermore, most of the previous records are from localities along or near Crowley's Ridge in the northeast with only one record represented in the south (Fig. 1). Other than the county records mentioned above, there have been few studies on this species in Arkansas (e.g., Trauth and Wilhide, 1988); nothing about the biology of *A. talpoideum* in Arkansas has been published. A life-history attribute documented in *A. talpoideum* in other parts of its range is the capability to reproduce in the larval stage, a condition known as paedomorphosis (see Semlitsch, 1987). Because paedomorphic populations of *A. talpoideum* occur syntopically with other *Ambystoma* in Arkansas (discussed below) and can be misidentified with other ambystomatid larvae, discovery of new localities for this species may have been hampered in the past. Consequently, the status of *A. talpoideum* (as a species of special concern in Arkansas) requires additional scrutiny (Reagan, 1974; Smith, 1984).

Since 1985, we have been conducting field investigations into the distribution and life history of several poorly-known amphibian species in Arkansas (e.g., Butterfield et a, 1989; Trauth et al., 1989; Trauth et al., 1990; Trauth and Robinette, 1990; Saugey and Trauth, 1991; Trauth, 1992; Trauth et al., 1992; Jamieson et al., 1993). During our field studies, we have encountered populations of *Ambystoma talpoideum* that begin to bridge a distributional hiatus between northeastern and southern populations (Fig. 1); in addition, recent collections have extended the range of the species into the Ouachita Mountains of Arkansas. In the following, we report on these new localities for *A. talpoideum* and also include comments on several paedomorphic populations. Voucher specimens are deposited in the Arkansas State University Museum of Zoology (ASUMZ).

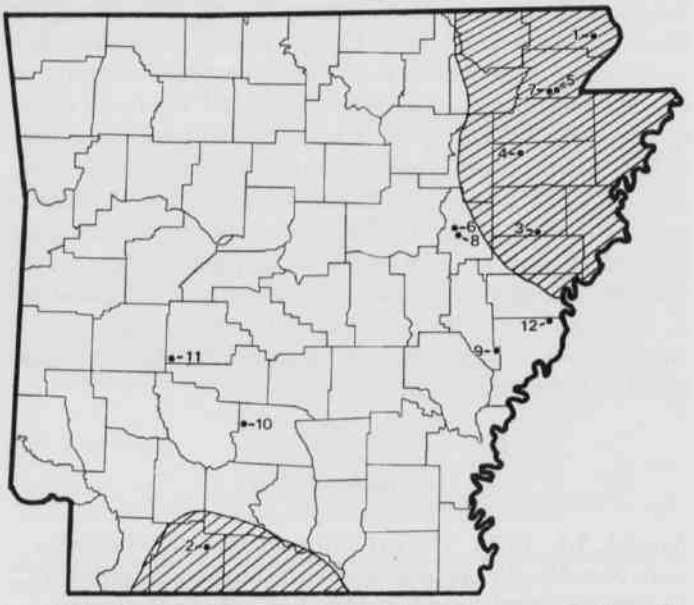

Fig. 1. Distribution of the mole salamander, *Ambystoma talpoideum*, in Arkansas. Diagonal lines depict range as illustrated by Conant and Collins (1991). Numbers 1-6 represent published county records (listed below), whereas numbers 7-12 are additional records discussed in text. 1-Clay (Parker, 1947); 2-Columbia (Robison and Winters, 1978); 3-Cross (Sutton and Paige, 1980); 4-Poinsett (Meshaka and Mclarty, 1988); 5-Greene (Meshaka et al., 1989), and 6-Woodruff (Plummer and Dye, 1992).

Locality 7 (Greene Co., T16N, R5E, S17).–This site, a cluster of gravel pits containing temporary pools of murky water, has been visited on several occasions since the discovery of *A. talpoideum* on 8 February 1988. Only paedomorphic individuals have been collected from these ponds.

Locality 8 (Woodruff Co., T6N, R3W, S27).–At this site, within the Black Swamp Wildlife Management Area (Arkansas Game & Fish Commission), researchers from the U. S. Army Engineer Waterways Experiment Station (Vicksburg, MS) conducted studies in 1988 and 1990 of terrestrial vertebrates using pitfall traps. Although over 650 amphibians were taken during the studies, only a single adult specimen of *A. talpoideum* (ASUMZ 16985) was collected on 5 November 1990.

Locality 9 (Monroe Co., T3S, R1E, S4).–On 11 April 1987, dip net sampling along St. Hwy 1 yielded a number of central newts (*Notophthalmus viridescens*) and small ambystomatid larvae that were later identified as *A. talpoideum*. The larvae possessed the distinctive pigmentary pattern of light stripes on the side of the head and gills with an irregularly outlined mid-lateral stripe (Volpe and Shoop, 1963). This larval sample represents a new county record for the species and places the species in the lower White River Basin of Arkansas.

Locality 10 (Dallas Co., T8S, R17W, S19).–While road cruising at night on 5 February 1991, two of us (BGC and DAS) collected an adult specimen crossing St. Hwy 7. The specimen represents a new county record and places the species within the Ouachita River Basin of southcentral Arkansas.

Locality 11 (Garland Co.; T3S, R22W, S34).–The collection by seining on 5 January 1993 of both adult and paedomophic specimens of *A. talpoideum* (ASUMZ 18625-18639) breeding in a wildlife pond in the Ouachita National Forest is the first record that extends the range of the species into a mountainous terrain in Arkansas. The pond, created in 1990 by the Forest Service, is situated in a clearing among pine trees; the area of the pond is approximately 0.1 and has a maximum depth of around 1.5 m. Eggs masses of transformed *A. talpoideum* and possibly those of *A. annulatum* and/or *A. maculatum* were present in the pond; we identified species based upon ovum/embryo size (Walls and Altig, 1986). Egg masses laid by paedomorphic individuals were loosely attached to vegetation and were distinguished mainly by their fragility, a characteristic observed in egg masses at other pond sites (e.g., Locality 5). The collection of egg masses and breeding individuals in early January at this site places the breeding phenophase of this population within the breeding interval observed in northeastern Arkansas (unpubl. data) and is similar to the breeding activity for the species in northwestern Louisiana (Hardy and Raymond, 1980).

Locality 12 (Phillips Co.; T1S, R4E, S1).–On 17 April 1993, a single paedomorphic adult was collected in a shallow roadside ditch within the St. Francis National Forest. This individual represents a new county record for the species.

In summary, our observations establish six new localities and four new county records for the mole salamander in Arkansas and extend the range of the species into the Ouachita Mountains. Paedomorphic populations of this species were found at three of the six new localities (in Greene, Garland, and Phillips counties). We recommend that the Forest Service now include *A. talpoideum* when addressing habitat considerations for salamanders (sensu Raymond and Hardy, 1991) in order to meet the goals outlined in the Amended Land and Resource Management Plan for the Ouachita National Forest (USDA-Forest Service, 1990).

Walter E. Meshaka, Brian P. Butterfield, Rusty B. McAllister, Chuck Long, Alan Christian, and Brady Richards are thanked for their field assistance. We dedicate this paper to the memory of Robert L. Cox, Jr., whose diligence in the field provided the initial Greene Co. records for *Ambystoma talpoideum* and whose compassion for herpetological pursuits was an inspiration to us all.

Literature Cited

Butterfield, B.P., W.E. Meshaka and **S.E. Trauth.** 1989. Fecundity and egg mass size of the Illinois chorus frog, *Pseudacris streckeri illinoensis* (Hylidae), from northeastern Arkansas. Southwest. Nat. 34:556-557.

Conant, R. 1958. A field guide to reptiles and amphibians of the United States and Canada east of the 100th meridian. Houghton Mifflin Co., Boston, 366 pp.

Conant, R. 1975. A field guide to reptiles and amphibians of eastern and central North America. Houghton Mifflin Co., Boston, 429 pp.

Conant, R. and **J.T. Collins.** 1991. A field guide to reptiles and amphibians of eastern and central North America. Houghton Mifflin Co., Boston, 450 pp.

Hardy, L.M. and **L.R. Raymond.** 1980. The breeding migration of the mole salamander, *Ambystoma talpoideum*, in Louisiana. J. Herpetol. 14:327-335.

Jamieson, D.H., S.E. Trauth and **C.T. McAllister.** 1993. Food habits of male bird-voiced treefrogs, *Hyla avivoca* (Anura: Hylidae), in Arkansas. Texas J. Sci. 45:45-49.

Meshaka, W.E., Jr. and **P. McLarty.**1988. Geographic distribution. *Ambystoma talpoideum*. Herpetol. Rev. 19:17.

Meshaka, W.E., Jr., B.P. Butterfield and **R.L. Cox.** 1989. Geographic distribution. *Ambystoma talpoideum*. Herpetol. Rev. 20:11.

Parker, M.V. 1947. Notes on the herpetology of Clay and

Green Counties, Arkansas. Proc. Arkansas Acad. Sci. 2:15-30.

Plummer, M.V. and **B.A. Dye.** 1992. Geographic distribution. *Ambystoma talpoideum*. Herpetol. Rev. 23:84.

Raymond, L.R. and **L.M. Hardy.** 1991. Effects of a clearcut on a population of the mole salamander, *Ambystoma talpoideum*, in an adjacent unaltered forest. J. Herpetol. 25:509-512.

Reagan, D.P. 1974. Threatened native amphibians of Arkansas. Pp. 93-99. *In* Arkansas natural area plan. Arkansas Dept. Planning, Little Rock, xvii + 248 pp.

Robison, H.W. and **S. Winters.** 1978. Geographic distribution. *Ambystoma talpoideum.* Herpetol. Rev. 9:21.

Saugey, D.A. and **S.E. Trauth.** 1991. Distribution and habitat utilization of the four-toed salamander, *Hemidactylium scutatum*, in the Ouachita Mountains of Arkansas. Proc. Arkansas Acad. Sci. 45:88-91.

Semlitsch, R.D. 1987. Density-dependent growth and fecundity in the paedomorphic salamander *Ambystoma talpoideum*. Ecology 68:1003-1008.

Smith, K.L. 1984. Animal species. Pp. 48-70, *In* Arkansas's natural heritage (B. Shepherd, ed.) August House, Little Rock, 116 pp.

Sutton, K.B. and **K.N. Paige.** 1980. Geographic distribution. *Ambystoma talpoideum.* Herpetol. Rev. 11:13.

Trauth, S.E. 1992. Distributional survey of the bird-voiced treefrog, *Hyla avivoca* (Anura: Hylidae), in Arkansas. Proc. Arkansas Acad. Sci. 46:80-82.

Trauth, S.E. and **J.W. Robinette.** 1990. Notes on the distribution, mating activity, and reproduction in the bird-voiced treefrog, *Hyla avivoca*, in Arkansas. Bull. Chicago Herpetol. Soc. 25:218-219.

Trauth, S.E. and **J.D. Wilhide.** 1988. Toe tip surface morphology in six species of salamanders, genus *Ambystoma* (Caudata: Ambystomatidae), from Arkansas using scanning electron microscopy. Proc. Arkansas Acad. Sci. 42:86-88.

Trauth, S.E., M.E. Cartwright and **W.E. Meshaka.** 1989. Reproduction in the wood frog, *Rana sylvatica* (Anura: Ranidae), from Arkansas. Proc. Arkansas Acad. Sci. 43:114-116.

Trauth, S.E., A. Holt, J. Davis and **P. Daniel.** 1992. A new state record for the plains leopard frog, *Rana blairi*, in Arkansas. Bull. Chicago Herpetol. Soc. 27:255.

Trauth, S.E., R.L. Cox, B.P. Butterfield, D.A. Saugey and **W.E. Meshaka.** 1990. Reproductive phenophases and clutch characteristics of selected Arkansas amphibians. Proc. Arkansas Acad. Sci. 44:107-113.

USDA-Forest Service. 1990. Amended land and resource management plan. Ouachita National Forest. Vol. 1, Hot Springs, Arkansas, 225 pp.

Volpe, E.P. and **C.R. Shoop.** 1963. Diagnosis of larvae of *Ambystoma talpoideum*. Copeia 1963: 444-446.

Walls, S.C. and **R. Altig.** 1986. Female reproductive biology and larval life history of *Ambystoma* salamanders: a comparison of egg size, hatchling size, and larval growth. Herpetologica 42:334-345.

Enlarged Posterior Maxillary Teeth in the Scarlet Snake, *Cemophora coccinea* (Serpentes: Colubridae), Using Scanning Electron Microscopy

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The scarlet snake, *Cemophora coccinea*, is a small-to-medium sized colubrid species that is distributed throughout Arkansas and the southeastern United States (Conant and Collins, 1991). The species is noted for its coloration (a red, black, and yellow-to-cream banding pattern), fossorial-to-semi-fossorial habits, and distinctively pointed snout. The scarlet snake is also infrequently encountered, and little is known about its biology in Arkansas other than its habitat preference for the sandy and red clay soils (Sutton and McDaniel, 1979; Trauth, 1982) in which it lays eggs and possibly searches for food in the form of the nesting eggs of other reptiles. Many authors have described the egg-eating habits of captive scarlet snakes (Minton and Bechtel, 1958; Palmer and Tregembo, 1970; Ernst and Barbour, 1989). Minton and Bechtel provided scarlet snakes with snake eggs and reported the presence of slits encircling the eggs following feeding episodes. The manner in which scarlet snakes pierce eggshells can be summarized as follows: 1) the jaws are extended forward over the end of an egg until enlarged maxillary teeth (EMT) are engaged into the eggshell, and 2) the egg is then chewed while, at the same time, the snake's body is wrapped over the egg to apply pressure to force out the egg contents. In the present study, the EMT (a morphological characteristic in this species; see Williams and Wilson, 1967) of *C. coccinea* were investigated using scanning electron microscopy to reveal the nature of dental ridges or other structural dental features of the teeth which enable these snakes to penetrate reptilian eggshells.

The left maxilla of six museum specimens (four adult and two juveniles) of *C. coccinea* collected from Arkansas was prepared for scanning electrom microscopy (SEM). Maxillae were excised from jaws using jewelers forceps and microscissors with the aid of a dissecting microscope. After extraneous tissues were removed from the bone, the samples were placed into 70% ethanol. Standard laboratory techniques were then employed to prepare bones for SEM. Maxillae were dehydrated in a graded series of ethanol and amyl acetate, dried in a critical point dryer, mounted onto copper specimen holders, coated with gold/palladium, and viewed with a JEOL 100 CXII TEMSCAN electron microscope at an accelerating voltage of 40 kV. Intact snakes and prepared tissues are deposited in the Arkansas State University Museum of Zoology and in the Electron Microscope Facility, respectively, at Arkansas State University.

Examination of the maxillary bones of *C. coccinea* by SEM revealed striking differences between anterior maxillary teeth and the EMT not only in size but also in dental ridge configuration (Figs. 1 and 2). There were no obvious differences in dental morphology between the sexes or between adults and juveniles. The anterior maxillary teeth exhibit labial dental ridges (Fig. 2B). Similar labial (as well as lingual) ridges have been observed in other colubrids, such as *Thamnophis elegans* (Wright et al., 1979) and *Tantilla gracilis* (Trauth, 1991). However, the EMT of *C. coccinea* appear to lack labial/lingual dental ridges (Fig. 1B). Instead, a very broad distal surface has a blade-like, slicing edge lying posteriad (and looking much like a teardrop in cross-sectional view) along the curvature of the tooth (Fig. 1B; 2C). A corresponding but less conspicuous dental ridge is found near the tooth tip on the mesial surface of EMT (Fig. 1C). This latter condition has also been noted on EMT of *Thamnophis elegans* (Wright et al., 1979) and various other colubrids (Vaeth et al., 1985) as viewed by SEM. On the other hand, *Tantilla gracilis* exhibits labial grooves on the EMT which constitute a rear-fanged or opisthoglyphous condition, and there are no mesial or distal dental ridges on these posterior maxillary teeth (Trauth, 1991).

The shifting of the labial/lingual dental ridges 90° to form a posterior blade and a short anterior ridge on the ETM has been reported in other snakes (Vaeth et al., 1985). No fluting patterns or striations were observed in the maxillary teeth of *C. coccinea* as compared to some colubrid species, whereas the EMT of some colubrids in the subfamily Natricinae possess blade-like posterior ridges (Vaeth et al., 1985).

During the seizing of reptilian eggs, the jaws of *C. coccinea* open widely to allow all maxillary teeth to contact the eggshell surface. In this process, the EMT extend forward; the mesial cutting edge (anterior tooth face) of EMT undoubtedly assists in the initial penetration of the

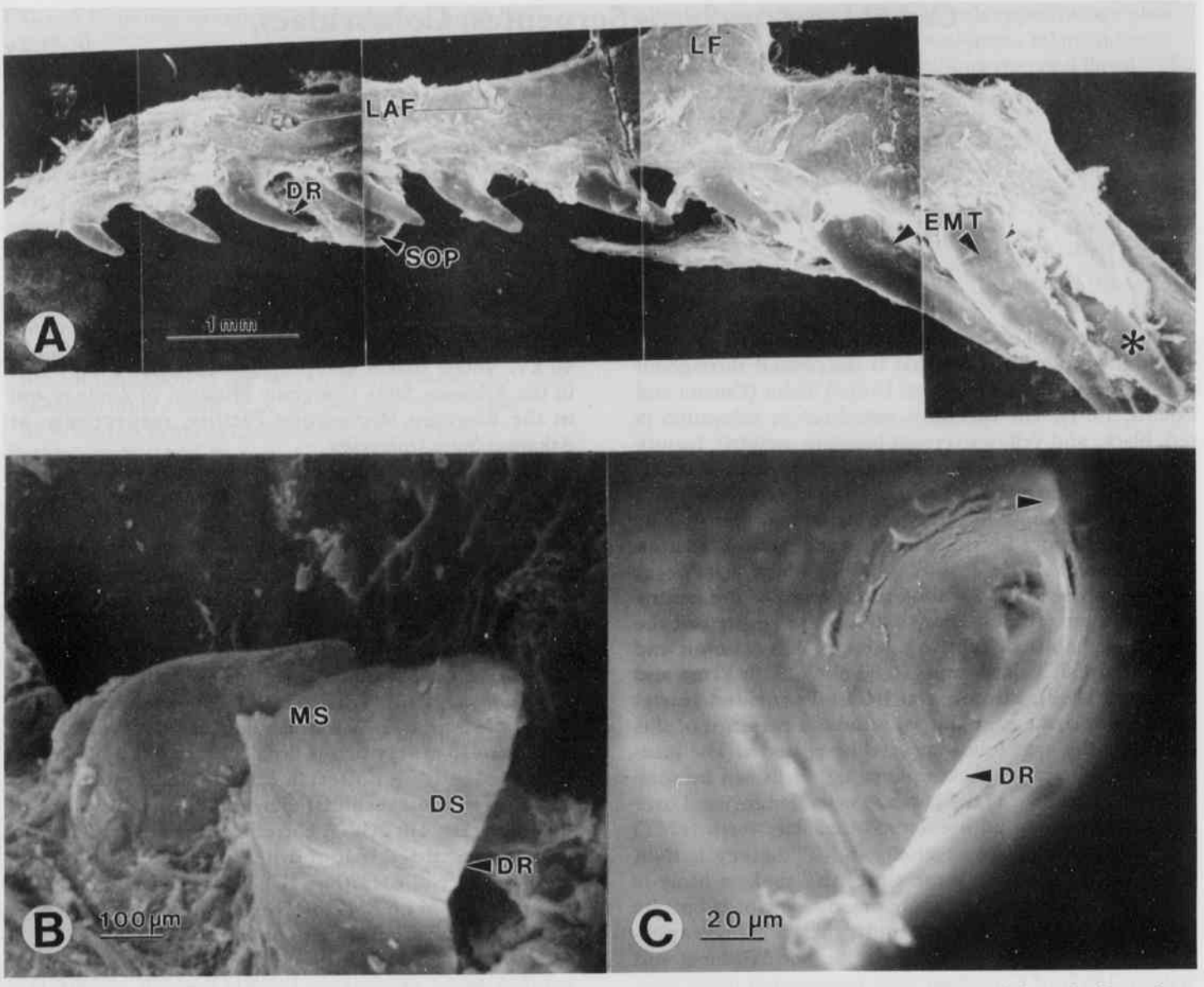

Fig. 1. Scanning electron micrographs of the left maxillary bone and enlarged maxillary teeth of an adult male *Cemophora coccinea*. A. Composite micrograph of entire maxillary bone showing two enlarged maxillary teeth (EMT) preceded by seven anterior teeth. A replacement EMT is identified by an asterisk. LAF = lateral anterior foramina; LF = lateral flange; SOP = suborbital process: DR = dental ridge on an anterior maxillary tooth. B. Magnification of two EMT illustrating the expanded distal surface (DS) which projects a prominent dental ridge (DR); MS = mesial surface. C. Ventral, end-on view of an enlarged maxillary tooth showing the cutting surface of the posterior dental ridge (DR) and a much smaller mesial dental ridge (pointer).

eggshell possibly by creating a trench or slight groove. As the mouth closes and the action of chewing begins, the EMT would follow the groove paths until the posterior surfaces of EMT are forced through the shell and could provide the maximal slitting capability by these teeth.

Literature Cited

Conant, R. and **J.T. Collins**. 1991. A field guide to reptiles and amphibians of eastern and central North America. Houghton Mifflin Co., Boston, 450 pp.

Ernst, C.H. and **R.W. Barbour**. 1989. Snakes of eastern

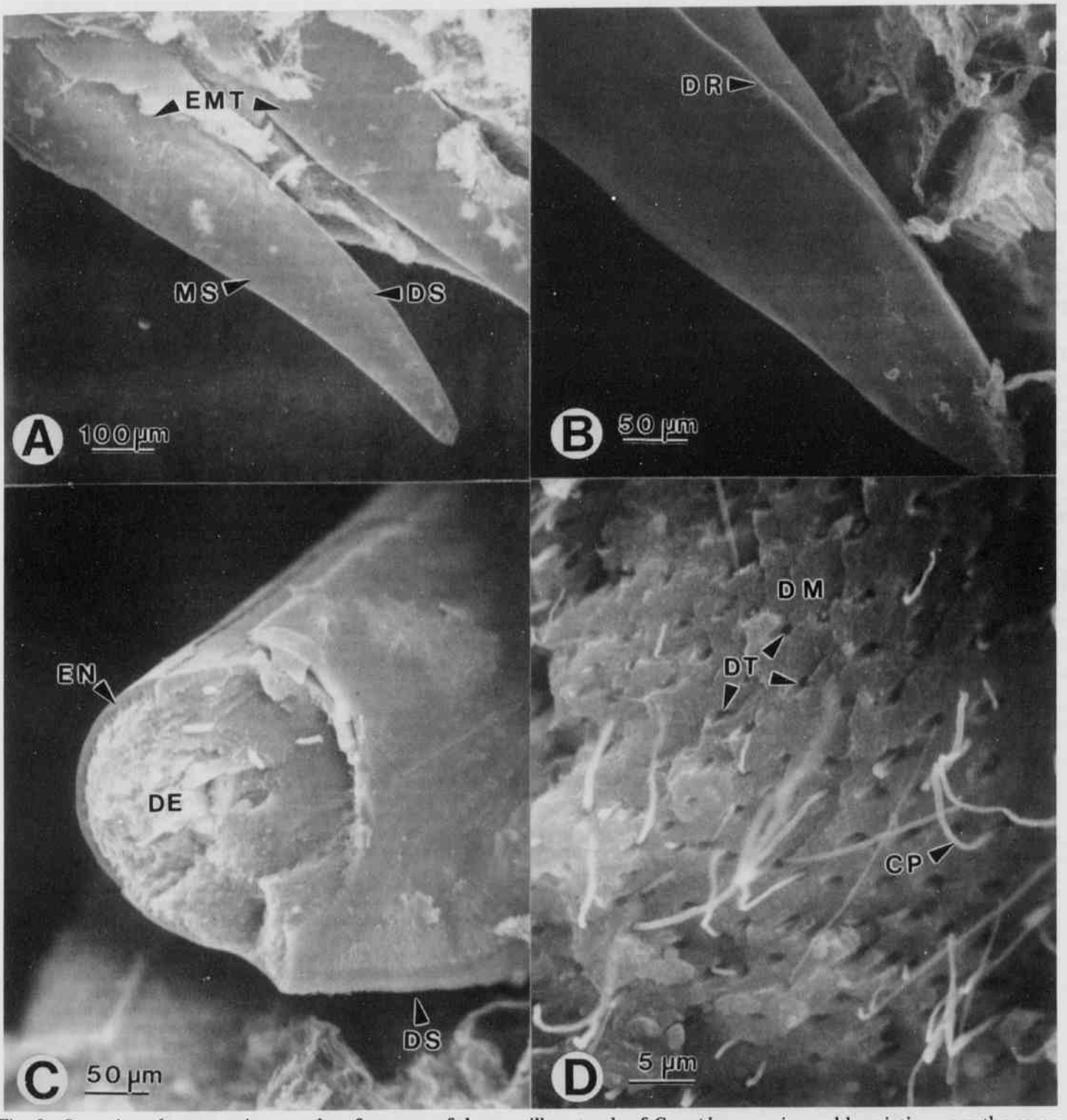

Fig. 2. Scanning electron micrographs of aspects of the maxillary teeth of *Cemophora coccinea*; abbreviations are the same as in Fig.1. A. Labial view of two EMT; note the lack of a labial dental ridge. B. Anterior maxillary tooth illustrating a conspicuous labial dental ridge. C. Ventrolateral view of a broken EMT revealing a thin outer enamel layer and a pulp of dentine. The prominent posterior dental ridge on the distal surface (DS) creates a tear-drop shape in transverse section. D. Magnification of C showing dentinal tubules (DT) interspersed within the dentine matrix (DM); CP = cytoplasmic process of odontoblast cell.

North America. George Mason Univ. Press, Fairfax, Virginia, 282 pp.

Minton, S.A., Jr. and **H.B. Betchel**. 1958. Another Indiana record of *Cemophora coccinea* and a note on egg-eating. Copeia 1958:47.

Palmer, W.M. and **G. Tregembo**. 1970. Notes on the natural history of the scarlet snake *Cemophora coccinea copei* Jan in North Carolina. Herpetologica 26:300-302.

Sutton, K.B. and **V.R. McDaniel**. 1979. Unusual concentration of scarlet snakes (*Cemophora coccinea*) in Village Creek State Park, Arkansas. Proc. Arkansas Acad. Sci. 33:92.

Trauth, S.E. 1982. *Cemophora coccinea* (Scarlet Snake). Reproduction. Herpetol. Rev. 13:126.

Trauth, S.E. 1991. Posterior maxillary fangs of the flathead snake, *Tantilla gracilis* (Serpentes: Colubridae), using scanning electron microscopy. Proc. Arkansas Acad. Sci. 45:133-136.

Vaeth, R.H., D.A. Rossman, and **W. Shoop**. 1985. Observations of tooth surface morphology in snakes. J. Herpetol. 19:20-36.

Williams, D.L. and **L.D. Wilson**. 1967. A review of the colubrid snake genus *Cemophora* Cope. Tulane Stud. Zool. 13:103-124.

Wright, D.L., K.V. Kardong and **K.L. Bentley**. 1979. The functional anatomy of the teeth of the western terrestrial garter snake, *Thamnophis elegans*. Herpetologica 35:223-228.

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Fleming, T. H. 1969. Population ecology of three species of neotropical rodents. Unpublished Ph.D. dissertation. Univ. Michigan, Ann Arbor, 231 pp.

Jones, I. C. 1957. The adrenal cortex. Cambridge Univ. Press, London, 316 pp.

Wright, P. L. 1966. Observations on the reproductive cycle of the American badger (*Taxidea taxus*). Pp. 27-45, *In* Comparative biology of reproduction in mammals (I. W. Rowlands, ed.) Academic Press, London, xxi + 559 pp.

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TABLE OF CONTENTS

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